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The Method of Gathering Meats from Shellfish by Chemical Shucking

(*With 1 Text-figure and 3 Tables*)

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In gathering meats from shellfish, the shucking methods by hand and heating have generally been used for a long time. The former is suitable for taste of meats. However, it not only requires many hands and costs but also has a defect of restriction on production. The latter is profitable for mass production but spoils taste and appearance of meats.

Recently, a new chemical shucking method was devised by Y. TOMIYASU and M. MIYAKE[1] and there arose an expectation that this method might develop into better one of mass production. The principle of the method is based on the dissolving action of chemicals on the union between shell and adductor muscle.

Since then, the author[2)3)4)] has been studying the method and obtained the practical results as follows.

I. Advantages and manufacturing process of the chemical shucking:

1. Labour-saving,
2. Application on a large scale without any fuel,
3. Shucked shell-meats are of a good appearance with little loss of taste and remain enzyme activities.

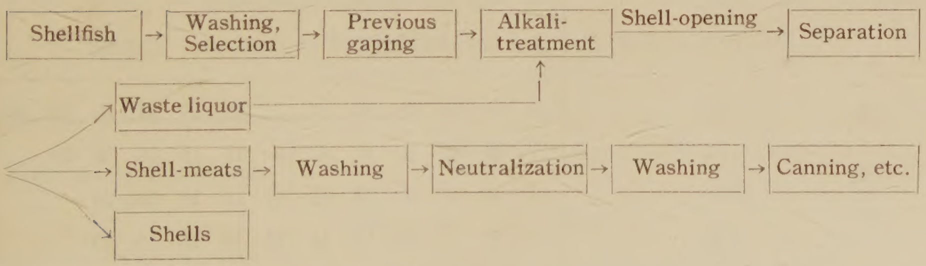

Fig. 1. Manufacturing process

II. Abilities of the chemicals detaching adductor muscle from shells:

First, the authors[1] searched for the chemicals which had the ability of detaching adductor muscle from shell. The chemicals examined were alkalies,

salts of alkaline earth metals, inorganic salts, alkaline salts of organic acids, and organic and inorganic acids.

Of these, sodium hydroxide, ammonium hydroxide, sodium carbonate, sodium sulfide were the most effective chemicals, and sodium perborate, ammonium carbonate, ammonium nitrate, potassium carbonate, 5–10 per cent solutions of sodium citrate, 5–10 per cent solutions of trichloracetic acid, and 0.1–0.5 per cent solutions of sulfuric acid had also the appreciable ability.

III. Comparative experiments between the shucking methods with caustic soda and sodium carbonate:

Of the chemicals found in the experiments, practicable ones may be caustic soda and sodium carbonate.

A. The rate of shell-opening and the time required for shell-opening:

Each twenty baby clams was immersed in 300 cc. of sodium hydroxide solution and sodium carbonate solution of varied concentrations at about 15°C and the numbers of the shells opened and the ligaments broken were counted. As shown in Table 1, caustic soda had strong opening power, e.g., 0.3 normal solution was equivalent to 2 normal sodium carbonate solution, but the rate of shell-opening in case of caustic soda decreased with the rising concentration, owing to its broken action on the ligament. The broken action was displayed more strongly in corbicula and ark-shell.

Table 1. Shell-opening with caustic soda and sodium carbonate.

Alkali		The number of the shells opened												
	Immersion period (hr.) / Conc. (n)	1	2	3	4	5	6	7	8	9	10	19	30	45
NaCH	0.3	0	0	0	0	6	11	$13_{(1)}$	$17_{(1)}$	$18_{(1)}$		$19_{(1)}$		
	0.5	0	$1_{(2)}$	$5_{(2)}$	$7_{(2)}$	$12_{(3)}$	$14_{(4)}$	$15_{(4)}$	$16_{(4)}$					
	1.0	$4_{(1)}$	$8_{(4)}$	$13_{(6)}$	$13_{(7)}$									
Na_2CO_3	0.5	0	0	0	0	0	5	7	10	13	14	15	18	20
	1.0	0	0	0	2	4	6	9	12	15	16	18	20	
	2.0	0	0	5	9	13	16	16	17	18	18	20		
	3.0	0	0	4	10	12	14	15	16	16	16	20		

The figures in parentheses indicate the number of the shells, the ligament of which was broken.

In case of caustic soda, the detachment of adductors was not so affected as the breakage of ligament, though both of them progressed in proportion to

concentration of caustic soda. Consequently, when the concentration of the alkaline solution is high, the breakage of ligament will happen readily before the detachment of adductors does, and the rate of shell-opening may be poor. On the contrary, if the concentration of sodium hydroxide solution is low, the rate of shell-opening may be good as the breakge of ligament is scarce, though it will take longer time for the shell-opening.

In case of sodium carbonate, little degradation of meats and no breakage of ligament will be found, though the time requiring for shell-opening may be long.

B. Putrefaction of alkaline solutions:

In practical cases, the alkaline solution which was used for the shell-opening may successively be used after the supplement for lost alkali. However, it is afraid of that if the soluble proteins and other soluble matters of shell-meats gradually dissolve into the alkaline solution, the putrefaction of the solution may take place. In fact, when a waste liquor of such dilute solution as 0.5 normal sodium carbonate was kept at 25°C for 24 hours, there increased putrefactive bacteria, and even in such a concentrated solution as 3 normal there occurred putrefaction.

Therefore, the control over the propagation of bacteria in the waste sodium carbonate solution must be taken into consideration. The employment of some antiseptics was effective for the purpose, for example, sodium carbonate solution containing five per cent or more of ethyl alcohol and that containing 0.2 per cent or more of sodium salicylate were effective. Sodium benzoate was inferior to sodium salicylate and the addition of sodium chloride to the alkaline solution was fovorable in all cases.

IV. Enzyme activity in the meats obtained with caustic soda:

The meats of baby clam obtained by alkaline shucking were minced and made into Shiokara (the mixture of meats and sodium chloride and after diges-

Table 2. Autolysis of SHIOKARA which was prepared from shell-meats obtained by alkali-treatment.

Time of alkali-treatment (hr.)	Soluble nitrogen (% in dry matter)		
	After 0 day	After 6 days	After 20 days
0	1.741	4.058	4.363
2.5	1.376	3.152	3.683
6.0	1.213	2.999	4.276
24.0	0.866	1.454	1.387

tion it becomes a food of good taste under enzyme action). The amount of soluble nitrogen increased during the digestion is shown in Table 2. It is shown that the enzyme activity in meats remained without destruction, though some decrease might happen.

V. Effects of time and treatment after gathering of shellfish on the rate of shell-opening:

In general, the shellfish gathered are processed after some hours. According to the experiments, the rate of shell-opening was better in the shellfish laid at a certain hour and in those immersed in fresh water before alkali-treatment than in the shellfish treated immediately after gathering.

VI. On various improved methods of chemical shucking:

Studies were carried on various methods to reduce the time for shell-opening and to raise the rate of shell-opening. This is of importance for practical purposes.

A. Chemicals effective for the suppression of swelling of ligament:

The ligament consists of two parts, the outer and the inner. The outer is insoluble in sodium hydroxide solution, while the inner swells first and solves later. If the shellfish is treated by a strong alkaline solution the outer will be destroyed by swelling of the inner; consequently, the shellfish cannot open the shells in spite of the detachment of adductor. If the inner consisting from albuminoid is prevented from the swelling, the rate of shell-opening will be raised without destroying the outer ligament. The shells of baby clams, removing the adductors and meat, were immered in solution of chemicals and the angles between two shells opened owing to the swelling of the inner ligament were compared with each another.

As a result, it was found that the addition of sodium chloride or ethyl alcohol to the alkaline solution was effective in preventing the breakage of ligament and raising the rate of shell-opening.

B. Methods to reduce the time for shell-opening:

To reduce the time for shell-opening, it is desirable to accelerate the velocity of alkaline solution entering into the shells. For this, two means may be expected; the one is by which the alkaline solution is forcibly introduced into the shells, the other is by which the solution is introduced into the shells gaped physiologically. As the former, a vacuum and a compressing methods were applied but there were no remarkable effects in both cases. As the latter, it was found that the relaxation of adductor owing to paralysis was successful.

a). Freezing method:

Baby clams were frozen at $-14\sim-18$°C for two minute and allowed to thaw in air, then the shellfish began to gape a little. When the shellfish thus gaped were immersed in 0.1 normal caustic soda solution at 20°C, all shell-

fish opened their shells widely within three hours and the meats were stripped of the shells within five hours. In such a dilute solution no shellfish could open without previous gaping. When baby clams frozen at $-10\sim-15°C$ for five hours were treated in 0.5 normal caustic soda solution at 25°C, all shellfish opened the shells within forty minutes. In 0.5 normal solution without previous gaping, half of the shellfish opened the shells and the other half could not open them on account of the breakage of ligament. When the shellfish frozen at $-5°C$ for fifteen minutes were treated with 8.7 per cent sodium carbonate solution containing 5 per cent sodium chloride, all shells were opened and the meats were stripped of entirely within three hours. The opening of the untreated hardly finished in forty-one hours. In corbiculas treated at $-10\sim-15°C$ for five minutes, all shellfish opened the shells within seventy minutes with 0.5 normal caustic soda solution at 25°C, but the shellfish without previous treatment could open the shells at the rate of 28 per cent and the rest could not open on account of the breakage of ligament.

There is problem in case of ark-shell, as they cannot open so widely the shells that the stripped meats must be liberated from the shells by hand.

b). Warm water method:

The fact that the shellfish paralysed under a certain temperature gapes a little was applied on the experiments. When baby clams, subjected to the warm water treatment at 43°C for twenty minutes, were immersed in 5 per cent sodium carbonate solution containing 5 per cent sodium chloride at 10°C, the complete detachment of adductor finished in seventeen hours, while those without previous treatment required thirty hours. When the temperature of water is 50–55°C (though the gaping begins quickly), the uniform shell-opening cannot be desired in alkali-treatment.

Table 3. The rate of shell-opening and the time required for shell-opening in various improved methods.

Shellfish	Method	Without previous treatment			With previous treatment		
		NaOH	NaOH+ 15% alc.	NaOH+ 15% NaCl	Freezing, $-10\sim-15°C$, 5 min.	Warm water, 43∼45, 3 min.	Alcohol, 16 hr.
Corbicula	Rate of shell-opening (%)	28	26	42	100	68	—
	Time for shell-opening (hr.)	4.5	5.5	6	70 min.	5	—
Baby clam	Rate of shell-opening (%)	50	72	68	100	86	68
	Time for shell-opening (hr.)	5	5	5	40 min.	4.5	5.5

c). Ethyl alcohol method:

It was found that the paralysis with ethyl alcohol was not perfect as the previous gaping.

C. Comparison of above methods:

The results of the comparative experiments on various chemical shucking methods which were done with each 50 baby clams and corbiculas at 25°C using 0.5 normal caustic soda solution are shown in Table 3.

As is shown in the table, it was found that the freezing method was most effective and the warm water came next.

VII. Summary:

1. Advantages and manufacturing process of the chemical shucking are described.

2. Abilities of the chemicals detaching adductor muscle from shell were investigated and it was found that of the chemicals caustic soda and sodium carbonate were the most practical.

3. Between the shucking methods with caustic soda and sodium carbonate the comparative experiments have been made and the results proved that these methods have their respective advantages and disadvantages, and therefore, for practical purposes these must be taken into consideration.

4. The enzyme activities in shell-meats can be maintained almost without being destroyed during the immersion in alkaline solution, if the duration of the alkali-treatment is suitable.

5. Improvements of the chemical shucking were done about the rate of shell-opening and the time required for opening of shells. Though addition of some chemicals effective for the suppression of swelling of ligament was favorable for preventing the breakage of ligament and raising the rate of shell-opening, the most effective means for this purpose was the previous gaping caused by means of paralysis. Comparing the improved methods, it was found that the freezing method was the most effective and the warm water method came next.

This work was done at the Faculty of Agriculture, Kyushu University and presented in the Japanese periodicals[1)2)3)4)].

I wish to express my thanks to Professor Yukio TOMIYASU for suggesting this investigation as well as for constant guidance in the course of the work.

Literatures

1) Yukio TOMIYASU and Masato MIYAKE: *Soc. Ferm. Tech.*, **27**, 109 (1949).
2) Masato MIYAKE: *Bull. Jap. Soc. Sci. Fish.*, **18**, 208 (1952).
3) Masato MIYAKE: *Bull. Jap. Soc. Sci. Fish.*, **18**, 213 (1952).
4) Masato MIYAKE: *Bull. Jap. Soc. Sci. Fish.*, **18**, 373 (1953).

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On the Similarity of the Osteological Characters Found between Owstoniidae and Cepolidae

(With 3 Figures)

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The object of the present paper is to present the osteological characters exhibited by the two families, Owstoniidae and Cepolidae, and to estimate the similarity between the two families under the comparison of the osteological characters observed in each case.

The species treated in this study are as follows: *Owstonia grammodon* FOWLER and *Pseudocepola taeniosoma* KAMOHARA, the representatives of Owstoniidae, and *Cepola schlegeli* (BLEEKER) and *Acanthccepola krusensterni* (T. and S.), the representatives of Cepolidae. Among these species, the external appearance of *Pseudocepola taeniosoma* KAMOHARA is seemed to suggest a phylogenetic similarity between the two families.

Osteological Description

I. Owstoniidae (*Owstonia grammodon* FOWLER: 138 mm. in standard length.)

A, **Cranium** (Fig. 1).

The cranium as viewed from above is widest at the sphenotics; it thence narrows forward in a long regular curves to the anterior margin of the frontals. As viewed from lateral, it is highest at the posterior margin of the supraoccipital crest; rather roundly convex in the interorbital region. Vomer is wide and rather flat, no teeth present on the ventral anterior portion. A longitudinal shallow groove situated on the ventral process of the vomer. Mesethmoid is next to the vomer, dorso-posteriorly by the frontals, laterally by the prefrontals, and ventrally by the ventral process of the vomer and parasphenoid. It is widest at the anterior portion but suddenly narrows at the portion between the prefrontals, The wing-like prefrontals are lateral to the mesethmoid and anterior to the frontals. The olfactory foramen is situated between the ethmoid and the prefrontal, each bone forming about half of it. The frontals cover the greater part of the dorsal surface of the cranium. The deeply embedded sensory canal longitudinally situated on either side of the median suture of these bones. This canal has five openings on the dorsal surface of this bone: the first opening situated at the anterior most part of the frontal, the second at the interorbital part, the third in the neighbourhood of the origin of the supraoccipital crest,

forming a circular position with its fellows on the opposite side, the fourth at the exterior to the third opening, and the fifth at the posterior end of the frontal which is articulated with the sphenotic. The rod-like parasphenoid is the prominent bone of the ventral surface of the cranium. The anterior bifurcated portion is articulated with the ventral process of the vomer. The posterior bifurcated end, forms an anterior half of the opening of the myodome which is anteriorly situated just below the exteriorly projected wing-like portion of the sphenotic. The parietals are situated on both sides of the supraoccipital, The outer side of each bone is slightly curved in the dorso-lateral direction, forming a rather distinguishable crest. The bones are surrounded anteriorly by the frontals, posteriorly by the epiotics, on the outer side by the pterotics, and on the inner side by the supraoccipital. The supraoccipital forms the dorso-posterior part of the cranium. It is bounded dorsally by the frontals, parietals and epiotics, and posteriorly by the epiotics and exoccipitals. The supraoccipital crest is longitudinally elongated from the posterior part of the boundary of the frontals to the posterior meeting end of the exoccipitals. The upper margin of this crest is rather rounded in the lateral outline. The epiotics are situated at the dorso-posterior corners of the cranium. The corners of the bones, articulated with the upper fork of the post-temporal, are rather prominent. The alisphenoids are bones of irregular shape, situated on the dorsal sides of the anterior opening into the brain case. The basisphenoid is a Y-shaped bone, situated on the anterior margin of the roof of the myodome. It is articulated dorsolaterally with the alisphenoids and prootics. A rather slender process is descended from it and attached to the parasphenoid. The sphenotics are prominent heavy bones forming the dorso-anterior corners of the postorbital portion of the cranium. The greater part of the dorsal surface of the bones is covered by the frontals. In the ventral surface, the bones are articulated anteriorly by the frontals, laterally by the alisphenoids, and posteriorly by the prootics. The prootics from the anterior portion of the lateral face of the brain case and the roof and walls of the myodome. The bones are bounded dorsally by the sphenotics and pterotics ventrally by the parasphenoid, anteriorly by the alisphenoid and basisphenoid, and posteriorly by the opisthotics, exoccipitals and basioccipital. The pterotics are situated on the posterior portion of the lateral margin of the cranium. At the ventro-lateral surface, the bones have a narrow facet for the articulation of the posterior head of the hyomandibular. The opisthotics are small plate-like bones, situated between the pterotics and the exoccipitals. The bones receive the insertion of the ligament from the ventral fork of the post-temporal. The exoccipitals form a part of the posterior as well as the lateral surface of the brain case. The lower part of the supraoccipital is inserted between the dorsal parts of the exoccipitals which form the lateral wall of the foramen magnum.

The basioccipital is a bone with a concave occipital condyle, articulating with the first vertebra. It is situated at the ventro-posterior end of the cranium.

B. **Upper jaw** (Fig. 1).

The upper jaw consists of a premaxillary and a maxillary. There are no supra-maxillaries. A row of canine-like teeth are sparsely set on the lower margin of premaxillary.

C. **Mandible** (Fig. 1).

The mandible contains three bones, the dentary, articular and angular. The dentary consists of two long slender arms into which the articular is inserted. A blunt ridge longitudinally extends from the head of articular to the anterior end of the dentary. There is a laterosensory canal along the ridge. The articular is a triangular-shaped bone provided with a long pointed process which is inserted into a V-shaped angle of the dentary. The angular is a small bone, stoutly articulating to the ventro-posterior part of the articular.

D. **Suspensorium and Opercular apparatus** (Fig. 1).

The palatine is situated on the external side of the vomer. This bone has a cylindrical and elongate anterior process which curves over the vomer, to which it is fastened below. The principal part of the palatine is triangular-shaped in lateral outline. The ventral margin of this part is not armed with teeth. The pterygoid is a slender, bow-shaped bone, articulating anteriorly with the palatine and entopterygoid, posteriorly with the quadrate. The quadrate is a flat triangular bone with a movable joint at the anterior angle to articulate with the lower jaw. There is a shallow groove to receive the lower portion of the preopercle. The entopterygoid is a thin bone articulating with the palatine and pterygoid. The inner free margin is situated at the side of the parasphenoid. The symplectic is a rod-like bone, the lower portion of which is adhered closely to the inner lateral face of the quadrate. The upper portion of this bone is more or less flattened, connected, to the lower end of the hyomandibular by a cartilage. The metapterygoid is a rather rectangular shaped. The upper flat wing-like portion of this bone is articulated with the lower anterior margin of the hyomandibular. There is a semicircular interosseous space between this bone and the lateral side of the hyomandibular process. The hyomandibular is a stout bone, with a broad upper portion and pole-like lower portion. The upper portion has three conspicuous condyles, of which the anterior and middle are for the cranium and posterior one for the opercle. The preopercle is a large bent bone of which the upper limb is situated closely in a groove of the posterior margin of the hyomandibular and lower limb to the quadrate. The preopercular sensory canal is well developed, running through the axis of the bone and opens at both extremities of the bone. The lower limb of this bone is armed with 5–6 spines. The interopercle is a flat bone, connecting by a ligament to the posterior

Fig. 1. Skeletons of *Owstonia grammodon* FOWLER ×5

ABBREVIATIONS

AN	angular	E	epiotic	HYO	hypocoracoid	PAL	palatine	QU	quadrate
AR	articular	EP	epihyal	HYP	hypercoracoid	PC	postclavicle	SC	supraclavicle
BA	basioccipital	EPTR	entopterygoid	IH	interhyal	PF	prefrontal	SPH	sphenotic
BR	branchiostegal ray	EX	exoccipital	METH	mesethmoid	PMX	premaxillary	SU	supraoccipital

end of the hyoid arch. The subopercle is a rather interesting shape. The basal portion is broad but the upper portion is extremely narrow. The opercle is a flat bone, more or less triangular in form, articulating with the posterior condyle of the hyomandibular. It is situated behind the preopercle, and above the subopercle.

E. **Hyoid apparatus.**

The glossohyal is a small median bone, embedded in the substance of the tongue, with a narrow cartilage at the broad anterior end. The Hypohyal forms the syphysis with its fellow of the other side behind the glossohyal. It is composed of two parts, upper and lower which are separated from each other by a triangular-shaped cartilage. The upper one is situated at a plane perpendicular to the lateral surface of the hyoid apparatus. The ceratohyal is a long flat bone, broader at the posterior region. Five branchiostegals are attached to the ventral margin of this bone. The epihyal is a flat and triangular bone. One branchiostegal is attached to the ventro-anterior part of this bone. The interhyal is a rod-like bone, articulated in a shallow socket in the dorso-posterior edge of the epihyal. The urohyal is a median, compressed bone widening posteriorly. It is articulated to the hypohyals at the anterior end, but free at the posterior end. The branchiostegals are flat, slender, curved bone. These are 6 in number, becoming longer, broader and more curved posteriorly.

F. **Shoulder girdle** (Fig. 1).

The post-temporal bone is a forked bone, situating on the highest part of the shoulder girdle. The dorsal branch is attached on the epiotic, and ventral branch is articulated to the opisthotic. The supraclavicle is an elongated triangular-shaped bone. The clavicle is a large bone of rather complex shape. It is broad at the dorsal part, narrow and pointed at the ventral part. The main part is consist of two wings, the exterior and inferior, which meet at the anterior margin. There is a pointed process on the dorso-anterior corner. Along the posterior margin of the inferior wing the hypercoracoid and hypocoracoid are attached. The hypercoracoid is a flat bone, having a large pectoral condyle for the first pectoral fin ray. A circular foramen is situated between the hypercoracoid and the clavicle. The hypocoracoid is a triangular-shaped bone, having no interosseous space between this bone and the clavicle. There are four actinosta, graduated in size and growing longer downward. The lowest one only is carried by the hypocoracoid. The postclavicle is a single bone. The upper anterior part is more or less oval-shaped. The lower posterior part is slenderly elongated, taking a sword-like appearance.

II. Owstoniidae (*Pseudocepola taeniosoma* KAMOHARA: 105 mm. in standard length).

A. **Cranium** (Fig. 2).

The body elements, consisting of the cranium and their arrangement are exactly same with the case of *Owstonia grammodon* FOWLER. The cranium as viewed from above is widest at the sphenotics; it thence narrows forward in long, regular curves to the anterior portions of the frontals. It is highest at the upper corner of the supraoccipital crest in lateral view. The vomer bears no teeth on the ventral anterior portion. A median longitudinal deep groove is situated on the ventral process. The olfactory foramen is pierced between the mesethmoid and the prefrontal, each bone forming about half of it. The frontal is a largest paired bone, forming the interorbital region anteriorly and a part of the postorbital region posteriorly. As in the case of *Owstonia grammodon* FOWLER, there is a deeply embedded sensory canal which is situated longitudinally on either side of the median suture of the frontals. This canal has five openings on the dorsal surface of the frontal: the first opening situated at the anteriormost part of the frontal, the second in the interorbital part, the third in the portion some distance from the origin of the supraoccipital crest, forming a triangular-shaped area with its fellow of the other side, the fourth in the exterior to the third opening, and the fifth at the posterior end of the frontal which is articulated with the sphenotic. The opening of the myodome is situated just below the exteriorly projected wing-like portion of the sphenotic. The supraoccipital crest is longitudinally situated at the pooterior part of the boundary of the frontals to the posterior meeting end of the exoccipitals. The upper margin of this crest is angulate in lateral outline. The auditory bulla is large and rather expanded.

B. **Other skeletons** (Fig. 2).

The supramaxillaries are not present. A row of canine-like teeth are sparsely set on the lower margin of premaxillary and the upper margin of dentary. The ventral margin of the palatine is not toothed. There is a semicircular interosseous space between the metapterygoid and the lateral side of the hyomandibular process. Four pungent and three feeble spines along the lower limb of the preopercle. The subopercle is a thin and flat bone of irregular outline, which is broadest ht the basal portion and it thence extremely narrows upward. Branchiostegals are six in number, which are flt, slender, curved bone becoming longer- broader and more curved posteriorly.

III. Cepolidae (*Cepola schlegeli* (BLEEKER):

A. **Cranium** (Fig. 3).

The cranium resembles to that of *Pseudocepola taeniosoma* KAMOHARA in general appearance. The vomer is toothless. The ventral process is not longitudinally concave. An olfactory foramen is obviously recognized between the prefrontal and the mesethmoid. The longitudinally situated sensory canal of the frontal has five openings on the dorsal surface of the bene. The position of

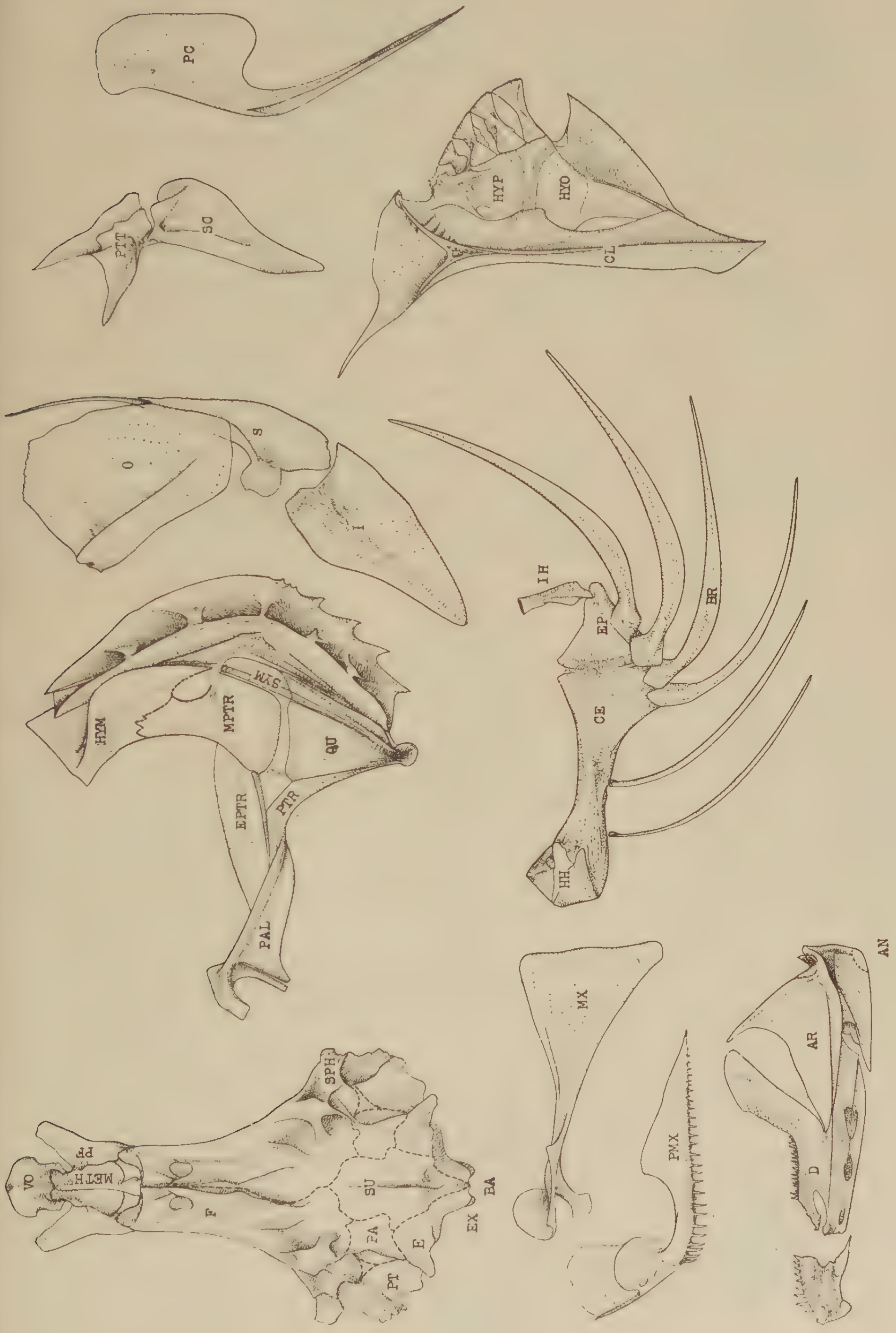

Fig. 2. Skeletons of *Pseudocepola taeniosoma* KAMOHARA ×8

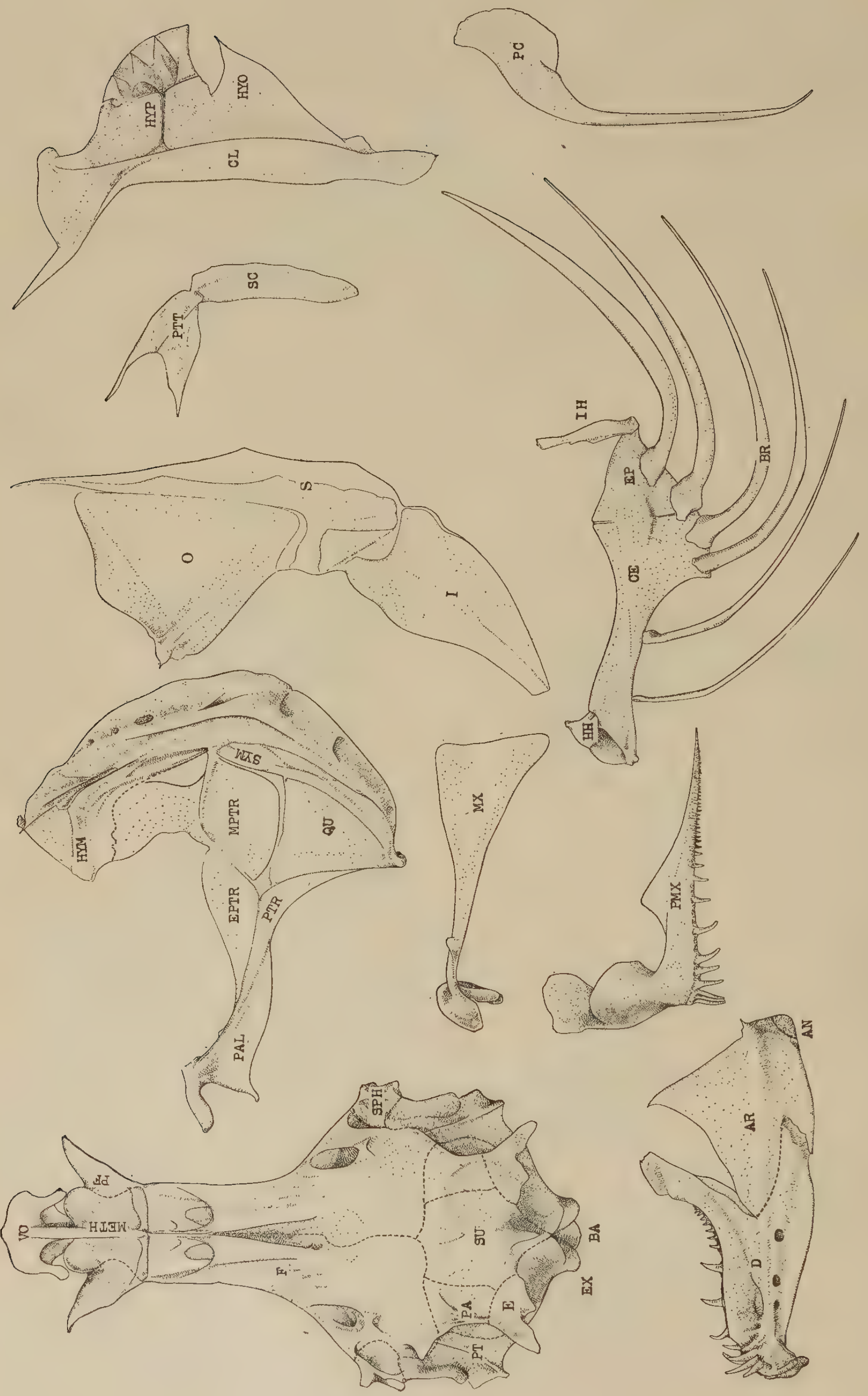

Fig. 3. Skeletons of *Cepola schlegeli* BLEEKER ×10

these openings are exactly correspond to those of *Pseudocepola taeniosoma* KAMOHARA. The myodome is opened in the anterior portion of the ventral surface of the cranium, just below the exteriorly projected wing-like portion of the sphenotic.

B. **Other skeletons** (Fig. 3).

Other skeletons show a striking resemblance to the cases of the former two species, that is, no supramaxillaries present; a row of canine-like teeth sparsely set on the premaxillary and dentary; the palatine is toothless; a semi-circular interosseous space between the metapterygoid and the lateral side of the hyomandibular process present; the flat, slender and curved branchiostegals are six in number.

IV. Cepolidae (*Acanthocepola krusensterni* (T. and S.): 198 mm. in standard length.)

This species bears close resemblance to *Cepola schlegeli* (BLEEKER) in the above osteological characters, except the presence of several sharp preopercular spines in the opercular apparatus of this species.

Remarks

Under the comparison of the foregoing osteological descriptions of four species, it is obviously recognized that several osteological characters, jaws, suspensorium, opercular apparatus, hyoid apparatus aud shoulder girdle have close resemblance among these species, but the crania of these species have some trifling differences in these general appearances in spite of the possesion of such important characters as the anterior position of the opening of the myodome, the olfactory foramen perforated between the prefrontal and the mesethmoid. Among the differences in these general appearances, the remarkable one is whether the interorbital part is roundly convex or not in the lateral outline. Unfortunately, *Owstonia grammodon* FOWLER, the representative of Owstoniidae, has an aberrant cranium, of which the interorbital part is roundly convex. But the cranium of *Pseudocepola taeniosoma* KAMOHARA the other representatives of Owstoniidae, are obviously characterized by having the flattish interorbital part, which is the general characteristic in the case of *Cepola schlegeli* (BLEEKER) and *Acanthocepola krusensterni* (T. and S.), the representatives of Cepolidae. In other words, *Pseudocepola taeniosoma* KAMOHARA, characterized by the above-mentioned skeletal characters, strongly suggests a taxonomic similarity between the two families, Owstoniidae and Cepolidae. Furthermore the close osteological similarities exhibited by these four species, representative of Owstoniidae and Cepolidae, are as follows:

1. The olfactory foramen is between the prefrontal and the mesethmoid, each bone forming about half of it.

2. The posterior opening of myodome is anteriorly situated just below the exteriorly projected wing-like portion of the sphenotic.
3. The vomer and the palatine are toothless.
4. The branchiostegals are six in number, becoming larger, broader and more curved posteriorly.
5. The postclavicle is a single bone.

Summarizing the above-mentioned facts, Owstoniidae represented by *Owstonia grammodon* FOWLER and *Pseudocepola taeniosoma* KAMOHARA, and Cepolidae represented by *Cepola schlegeli* (BLEEKER) and *Acanthocepola krusensterni* (T. and S.) are similar in several important osteological characters. Furthermore, in addition to the osteological similarities. the external appearances of the species referable to the two families are obviously similar in the following two characters:

1. Dorsal and anal fins are not divided respectively, and these bases are relatively elongated.

2. Dorsal and anal spines are not sharp and solid but flexible and reduced.

Therefore, the present authors propose that Owstoniidae should be included within Cepolidae.

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Notes on the Young of Rare Fish, *Taractes steindachneri* (DÖDERLEIN)

(*With 1 Figure and 1 Table*)

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In 1884, DÖDERLEIN published the original description of this species based on the specimen (250 mm. in total length) collected at Tokyo, Japan. In 1940, KAMOHARA published the full description of this species based on several specimens (170–500 mm. in total length) collected from Tosa, Shikoku, Japan, together with the figure of young specimen (170 mm. in total length).

Among the fishes collected off Owashi, Mie Prefecture, Japan, at a depth of about 200 fathoms on November, 1953, the youngest specimen of *Taractes steindachneri* (DÖDERLEIN) was found. Upon the careful examination of this specimen, we remarked some peculiar characteristics of the young stage.

Authors appreciate their heartily thanks to Prof. KIYOMATSU MATSUBARA of Kyoto University for his valuable help.

Taractes steindachneri (DÖDERLEIN)

Japanese name: Manzai-Uo

Argo steindachneri DÖDERLEIN, 1884, p. 174; Tokyo, Japan (original description)-JORDAN, TANAKA and SNYDER, 1913, p. 134. (listed) (Owing the preoccupation of the generic name, *Argo* in mollusks, by BOHADSCH, 1761, the generic name, *Taractes* was used in this case.)-TANAKA, 1931, p. 24. (listed)-OKADA and MATSUBARA, 1938, p. 157. (listed)-KAMOHARA, 1940, pp. 155–156. Tosa, Shikoku, Japan (Description based on Several specimens 170–500 mm. in total length, and figure based on specimen 170 mm. in total length were given.). KAMOHARA, 1952, p. 33. (listed)-MATSUBARA, 1955, p. 542. (listed).

Fig. 1. Taractes steindachneri (Döderlein). Japanese name: Manzai-Uo 4/5.

Specimen under examination: 70.5 mm. in standard length (82.0 mm. in total length.)

Description: D. IV. 31; A. III. 24; p. 19; V. I. 6. Branchiostegals 7. Gill-rakers on Ist arch 5+11 16. Scales in a median longitudinal series 35.

Head 2.94 in standard length; depth at origin of dorsal 2.08; the same at origin of anal 2.10; width at origin of dorsal 4.73; the same at origin of anal 5.42; distance from snout to origin of dorsal 2.37; distance from snout to origin of anal 1.66.; distance from snout to origin of ventral 2.94; distance from snout to anus 1.90. Eye 3.12 in head; snout 4.61; interorbital space 2.67; length of upper jaw 1.88; depth of caudal peduncle 4.36; longest gill-raker on first arch 10.43.

Body deep and much compressed, deepest at origin of dorsal, slightly deeper than the depth at origin of anal. Profile from nuchal region to origin of dorsal rather steep and somewhat arched. Interorbital space flat, not convex like other specimens of this species collected by the two ichthyologists in the past. Base of dorsal slightly arched. Profile from mandible to origin of anal gently and evenly arched. Base of anal approximately straight. Caudal peduncle constricted, its depth 1.13 in its length. Mouth oblique, moderate sized; lower jaw very slightly longer than the upper. Maxillary scaled, widely enlarged posteriorly, its distal end approximately reaching to the posterior margin of eye. Small canine-like teeth rather closely set in one or two series on jaws, anterior teeth of each jaw obliquely projected outerward. Vomer and palatines toothless. Snout short, about 1.50 times of it as long as horizontal diameter of eye. Eye large, its horizontal diameter much longer than snout. Interorbital space rather wide, about 2.07 in head. Two nostrils on each side, these openings nearly rounded. Preopercular, subopercular and interopercular margins serrated. Gill-rakers on first arch 5+11 16, 4 of upper and 4 of lower rudimentary developed, each gill-raker with 1–3 accessory spines. Pseudobranchiae well developed.

Dorsal inserted just above the posterior margin of opercle, its base much longer than anal base. Several anterior rays of dorsal filamentously elongated, the fourth ray is the longest, about 0.63 times of it as long as head. Anal originated below the tenth dorsal ray, its appearance similar to that of dorsal, the fourth ray is the longest, about 0.73 times of it as long as head. Pectoral rather long, 1.80 in head, extending posteriorly somewhat passing beyond the origin of anal. Ventral rather short, 2.45 in head, situating under the upper end of base of pectoral. Caudal lunate. Situation of anus is close to origin of anal, distance between the two 1.73 in snout.

Scales rather large, varying greatly in size, relatively larger along the sides of body, relatively smaller on head, belly, back and base of each fin. Each scale emarginated posteriorly and provided with a large median spinosus and

several small radiating ridges ending in small sharp spines. No scales on snout, mandible and interorbital space. Dorsal, anal and caudal sheathed with small scales in these basal parts.

Color in formalin grayish brown, much lighter beneath; pectoral, ventral and caudal rather pale, other fins all brownish black.

Remarks: The present description is nearly agreed with the descriptions offered by DÖDERLEIN (1884) and KAMOHARA (1940) but rather remarkable differences are found in several characters indicated in Table 1.

Table 1.

	Present specimen	DÖDERLEIN's specimen	KAMOHARA's specimens
Total length	82.0 mm.	250 mm.	170–500 mm.
Standard length	70.5 mm.	195 mm.	
Head	2.94 in standard length	3.2 in standard length	3.1–3.2 in standard length
Depth	2.09 in standard length	1.6 in standard length	1.5–1.7 in standard length
Eye	3.12 in head	4.1 in head	4.2–4.3 in head
Interorbital space	2.67 in head	2.8 in head	2.4 in head
Depth of caudal peduncle	4.36 in head	3.7 in head	3.8–4.3 in head
Dorsal fin	IV. 31	IV. 30	IV. 28–30
Ventral fin	1.6	1.5	
Appearance of interorbital space	flat	convex	convex
Each scale on head and anterior part of body	very coarse and with a median spinosus process	smooth and without median spinosus process	

We suggest that the above-mentioned distinct characters may be due to the differences exhibited characteristic of the younger stage of the present species.

Literatures

JORDAN, D. S., TANAKA, S., and SNYDER, J. O. 1913: A catalogue of the fishes of Japan. Jour. Coll. Sci. Imp. Univ. Tokyo, 33, (1), pp. 1–497.

KAMOHARA, T. 1940: Fauna Nipponica, vol. XV, fas. II. no. V, Scombroidei (Exclusive of Carangiforms), pp. 1–225. Sanseido Tokyo.

KAMOHARA, T. 1952: Revised description of the off-shore bottom-fishes of Prov. Tosa, Shikoku, Japan. Rep. Kochi Univ., Nat. Sci. (3), pp. 1–122.

MATSUBARA, K. 1955: Fish Morphology and Hierarchy. Part 1, pp. 1-789. Ishizaki Shoten Tokyo.

OKADA, Y. and K. MATSUBARA 1938: Keys to the fishes and fish-like animals of Japan. pp. 1–584. Sanseido Tokyo.

STEINDACHNER, and L. DODERLEIN 1884: Beitrage zur Kentniss der Fische Japan's (III) Denkschr. Acad. Wiss. Wien, 48, pp. 1–40.

TANAKA, S. 1931: On the distribution of fishes in Japanese waters. Jour. Fac. Sci. Imp. Univ. Tokyo, sec. 4, Zoology, 3, (1), pp. 1–90.

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Studies on Pearl Formation Mechanism by Radioautography*

(*With 1 Plate and 1 Table*)

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Many studies[1,2,3] have been recently carried out on the shell and pearl formation and the mechanism of the formation should be considered as results of the metabolism carried by the cells of the mantle or the pearl sac.

Recent studies deal with the enzyme or other substances relating to the metabolism; in them, Ca^{45} [4,5,6,7,8,9], glycogen and polysaccharide[10,11], nucleic acid[12], and phosphatase[18] have been observed.

BEVELANDER (1952) observed the localization and the deposition of Ca^{45} and P^{32} in the mantle and shell by radioautographic method[9]. He found that Ca^{45} was concentrated on the periphery of the mantle and also incorporated into the crystals of calcium carbonate in the newly-formed shell, while P^{32} was localized on the inner margin of the mantle in the region of the mucous glands. It was also incorporated in the periostracum surrounding the crystals.

Moreover, biochemical studies were carried out on the calcium metabolism in *Crassostrea virginica* GMELIN by WILBUR and JODREY (1952)[13] and JODREY (1952)[14], in *Pinctada martensii* (DUNKER) and *Hyriopsis schlegelii* (MARTENS) by MATSUI et al[15] and in *Hyriopsis schlegelii* (MARTENS) by HORIGUCHI et al[16]. According to the results in *Crassostrea virginica*, uptake of Ca^{45} by mantle edge was completed in one hour. After the lapse of 2 or 4 hours the mantle took up as much as Ca^{45} it can accumulate. The rate of disappearance was very high; most of the Ca^{45} disappeared in half an hour.

The present authors have kept *Pinctada martensii* (DUNNER) in aquaria to which Ca^{45} and P^{32} were added, and observed the localization of the radioactive isotopes in the mantle and in the pearl. Above all, the difference of their distribution in different part of the mantle have been examined. The object of these experiments lies in the application of their results to the practical pearl culture.

Materials and methods

Pinctada martensii (DUNKER) of 3 years old cultured in the bed of the Fisheries Experimental Station, Mie Prefecture, were used for the experiments.

* This paper was presented to International Conference of the Peaceful Uses of Atomic Energy, Geneva, 1955.

1) Preparation of breeding sea water containing radioactive isotopes.

Imported P^{32} was diluted 10 times with distilled water, to which was added 1000 volume of sea water. This sea water showed radioactivity of 60 counts/min./c.c.. In the same way, sea water containing Ca^{45} was prepared. It showed 1216 counts/min./c.c.. Radioactivity was measured by the method of HORIGUCHI et al[16].

2) Nucleus insertion and breeding of *Pinctada martensii*.

On August 1, two paraffin neucleii (spherical) were inserted into each of the pearl oysters numbering 40 by ordinary method. Operated pearl oysters were cultured for 23 days in the sea and then brought to the laboratory. They were divided into two groups, each of which bred in a separate aquarium containing sea water with P^{32} and Ca^{45}, respectively.

The volume of the sea water was one liter/one oyster/two hours. The temperature of the sea water was varied from 27°C to 29°C during the experiments. The PH of the radioactive sea water was 8.3.

After the interval of 2 and 10 hours, the pearl oysters were kept in the normal sea water for 10 minutes and then washed well with sea water.

3) Procedures for radioautograph.

Animals were fixed in 80% alcohol for 34 hours, with alcohol renewed for every 8 hours. After fixation the shell valves were removed and the mantles were taken out of the body and pasted on glass plates. The mantles, when dried up, were immersed in 8% alcohol-ether solution of celloidin for a moment, to be covered with a thin membrane of celloidin. Each mantle was made to contact a FUJI-2E 15 contact plate with a sheet of medical paper between them. The plates with mantles were tightly wrapped with black paper.

Some of the fixed pearl sacs or mantles were cut into thin sections (15μ in thickness) in the ordinary way and placed on the slide glasses, deparaffinized with xylol and covered with thin membrane of celloidin. In this case, stripping plates were used.

4) Time of exposure.

The time of exposure followed the proceeding model experiments. In P^{32} experiments, the time of exposure was 8 days in the contact method and 30 days in the stripping method. It was 180 days in Ca^{45}.

5) Development and fixation.

Plates were developed with EASTMAN D-19 or FUJI Rendol and fixed with first method of YAGODA[17] or FUJI-FH-H.

6) Control experiment.

As the control, pearl oysters fixed in alcohol were washed with sea water, and placed in sea water containing radioactive isotopes for 2 and 10 hours. They were then treated in the same way as the above mentioned.

Observations

1) Localization of P^{32}.

a) Mantle.

Radioautographs of the mantle of the pearl oyster bred for 2 or 10 hours in P^{32} water showed that more silver grains were blackened on the periphery. The periphery of the mantle is divided into inner, middle and shell folds, where basophilic and acidphilic glands are localized. P^{32} was found abundant in the epithelial cells and sub-epithelial zone of the inner and outer folds, esp. in the inner one.

It was also localized in the glands of the outer part of the mantle. Two parts can be discernible in the glands; one is filled up with cytoplasmic contents, while the other is occupied with many vacuoles. P^{32} was mostly found in the former. The concentration of P^{32} in the muscles of the mantle seemed lower than in other parts, but a large amount of it was localized in the blood vessels and wander cells in the muscles.

No difference was observed in the localization of P^{32} in the mantles between 2 hours' ones and 10 hours'.

b) Pearl and pearl sac.

During the cultivation for 23 days, pearl sac had been formed completely in the gonads of pearl oysters but not any calcareous layer on the paraffin nucleii. The nucleii were covered with conchiolin layers only.

In this case, too, P^{32} was localized in the epithelial cells of the pearl sacs. Moreover, a relative amount of P^{32} deposited in the conchiolin layers of the pearls.

The distribution of P^{32} in the conchiolin layers was not homogenous and in some part of the layer, it was found at the basal part, and in the other, localized in the middle and upper.

It was also localized in the cytoplasm of the eggs and in the mid-gut glands.

2) Localization of Ca^{45}.

Thin sections were not prepared in the experiment for Ca^{45}, and its localization was observed only with the contact method, so detail observations were not made.

But it was found that Ca^{45} was localized in all parts of the mantle with larger concentration in the periphery. Ca^{45} was found taken by the nacre of the shell in 2 hours.

Consideration

If P^{32} is incorporated by the contamination, it should be localized along the edges of the mounted sections on the slide. But in the present radioauto-

graphs, blackened silver grains were not found along the edges. This suggests that the present radioautographs were registered by the radioactivity of P^{32} taken up in the body of the pearl oyster.

Contraction of the mantle was greater in the P^{32} experiment than the Ca^{45} one. So it is unadvisable to discuss the distribution of P^{32} by figure 2. But the part where heavy deposition of P^{32} appeared (the left central part in figure 2) seems to correspond with that from which the byssus is secreted.

The number of silver grains per 100 μ^2 blackened by the radioactivity of P^{32} was calculated under the microscope in randomly selected 5 parts in each of the following positions: outer epithelium, outer sub-epithelial zone, inner epithelium, inner sub-epithelial zone, muscle, blood vessel, basophilic gland and back ground. These calculations were made in each of the 3 specimens of radioautographs which were selected by random sampling. Thus the average number of grains in each position was calculated. The number of back ground was 29.2. Table 1 shows the number subtracted 29.2 from that of each position.

Table 1. Calculation of the grains per 100 μ^2

Position	Plate 1	Plate 2	Plate 3	Mean
Outer epithelium	57.2	70.2	50.8	59.3
Outer sub-epithelial zone	46.8	70.2	64.6	61.6
Inner epithelium	54.6	82.2	43.6	60.2
Inner sub-epithelial zone	49.6	76.8	60.8	68.3
Muscle	41.6	40.6	39.0	39.9
Blood vessel	59.2	68.8	65.2	64.7
Basophilic gland	55.4	84.5	54.2	65.2

Significance of the difference occurring in number by the position was examined by the table 1. It was found that significant difference with the level of 1% occurred between the muscle and other positions. In other positions, there was found no significant difference at 5% level. Mean value of outer zone (including outer epithelium and outer sub-epithelial zone) and inner zone (including inner epithelium and inner sub-epithelial zone) are 64.3 and 60.4, respectively. Their difference was not significant. However it would become significant if more examples are examined.

BEVELANDER reported that P^{32} was especially concentrated in the sub-epithelial zone of inner surface or mucous gland of the mantle. The present authors also found its abundancy in the epithelium as well as in the sub-epithelial zone and basophilic gland.

Heavy depostion of P^{32} was found in the epithelium of the pearl sac, and it was also localized with high concentration in the conchiolin layers of the pearl. It is reported from the results of the chemical analysis that content of phosphorous in the cultured pearl is only a trace, but results of the present experiment shows

that P^{32} can easily be taken up by the pearl oyster to form the conchiolin layer of the pearl. Moreover, the fact that localization of P^{32} in the layer of the pearl is not homogeneous shows that its deposition did not take place at the same time over the surface of the pearl but only partially. This fact will prove one of the authors' idea of pearl formation[19] that the layers of the pearl are not formed evenly over the whole surface at one time, but locally by the deposition of its constituents.

As for Ca^{45}, BEVELANDER observed that it was incorporated in the calcium carbonate crystals in the regenerated shell of Pinna.

The radioautographic studies of the thin sections of the mantle have not been finished yet, so a definite conclusion is yet to be drawn. However, it is found that uptake of Ca^{45} can be detected by radioautographic method in 2 and 10 hours' breeding. Ca^{45} was localized generally in the mantle, especially abundant in the periphery.

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Summary

1) P^{32} was taken up by *Pinctada martensii* (DUNKER) in 2 or 10 hours' breeding in aquarium.

2) It was localized in the outer epithelium, outer sub-epithelial zone, inner epithelium, inner sub-epithelial zone, muscle, blood vessel, basophilic gland, with the highest concentration in the inner sub-epithelial zone and least in the muscle.

3) It was deposited in the epithelium of the pearl sac, and conchiolin layer of the pearl.

4) Ca^{45} was localized generally in the mantle especially in its periphery.

References

1) RAWAITZ, B., 1888. Der Mantlerand der Acephalen. 1 Teil: Ostreacea. *Jena. zeit. für Nat.*, **22**, 415–456.
2) ROBERTSON, J. D., 1941. The function and metabolism of calcium in the invertebrata. *Biol. Rev.*, **16**, 106–133.
3) OJIMA, Y., WATANABE, T., 1953. Studies on the pearl-sac in molluscs. *Ann. Studies*, 1. published by *Kwansai Gakuin Univ.*, **1**, 57–65.
4) OJIMA, Y., 1952. Histological studies on the mantle of pearl oyster., *Cytologia*, **17**, 134–143.

5) HAYASHI, K., 1938. Detection of calcium in molluscan mantles. I. *Anodonta* and *Cristaria*., *Annot. Zool. Japan.*, **17**, 95–104.
6) HAYASHI, K., 1938. On the so-called bottle-shaped glands of *Pinctada martensii*, with special reference to Tanaka's theory of pearl formation., *Annot. Zool. Japan*, **17**, 105–106.
7) HAYASHI, K., 1939. Detection of calcium in Molluscan mantles. II. *Euhadra callizona* KOBELT., *Annot. Zool, Japan*, **18**, 1–10.
8) TSUJII, T., will be published.
9) BEVELANDER, G., 1952. Calcification in molluscs. III. Intake and deposition of ca^{45} and P^{32} in relation to shell formation. *Biol. Bull.*, **102**, 9–15.
10) KADO, Y., 1953. Distribution of Polysaccharides in mantle tissues of *Venerupis semidecussata* (BIVALVE). *J. Sci.* of the *Hiroshima Univ.* s. *B. 1*, **14**, 1–14.
11) TSUJII, T. will be published.
12) TSUJII, T., 1955. Histochemical studies of nucleic acids on shell-and culture pearl formation., *Bull.* of the *Biogeograph. Soc. Japan*, **16–19**, 88–93.
13) WILBUR, K. M. and JODREY, L. H., 1952. Studies on shell formation. I. Measurement of the rate of shell formation using ca^{45}, *Biol. Bull.*, **103**, 269–276.
14) JODREY, L. H., 1953. Studies on shell formation. III. Measurements of calcium deposition in shell and calcium turnover in mantle tissue using the mantle-shell preparation and ca^{45}. *Biol. Bull.*, **104**, 398–407.
15) MATSUI, K., 1952. Deposition of ca^{45} in fresh water pearl mussel and pearl oyster (in Japanese). *Zool. Mag.*, **61**, 119.
16) HORIGUCHI, Y., OKADA, Y., MIYAKE, M., YOSHII, G., INOUE, Y., MIYAMURA, M. 1954. Biochemical studies with radioactive isotopes on *Pteria* (*Pinctada*) *martensii* (DUNKER) and *Hyriopsis schlegelii* (v. MARTEN). *Bull. Japan. Soc. Sci. Fish.*, **20**, 101–106.
17) YAGODA, H. 1949. Radioactive measurements with nuclear emulsion. John wiley & Sons. Inc., New York.
18) OJIMA, Y. and IKENAGA, S., 1954. Studies on the pearl-sac in molluscs. II. Distribution of alkaline phosphatase in the mantle and pearl-sac of the fresh water pearl mussel. *Zool. Mag.*, **63**, 26–29.
19) WATABE, N., 1950. On the laminary structure of cultured pearls. *J. Fuji Pearl Inst.* ,**1**, 3–7.

Explanation of the Plate XV

Fig. 1. Photograph of a pearl-oyster mantle.

Fig. 2. Radioautograph of the pearl-oyster mantle of Fig. 1., showing distribution of P^{32} Heavy deposit of P^{32} appear in the periphery of the mantle. Emulsion exposed 8 days. Contact method.

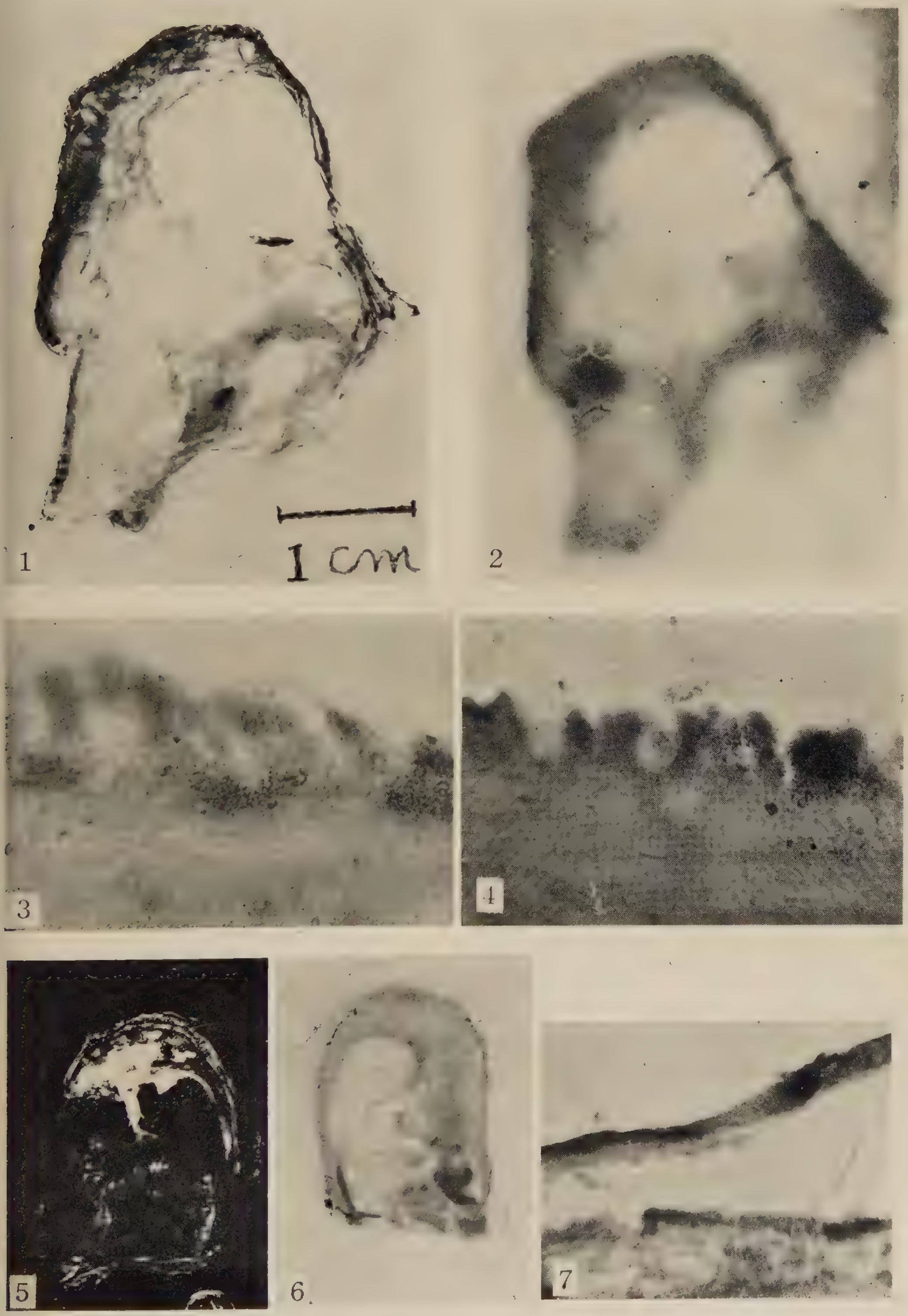
Fig. 3. Radioautograph of section of mantle of pearl-oyster. Localization of P^{32} is shown by the blackened sub-epithelial areas of inner surface of the mantle. Emulsion exposed 30 days. ×1000. Stripping method.

Fig. 4. Radioautograph of section of mantle of pearl-oyster. Localization of P^{32} is shown by blackened epithelial areas of inner surface of the mantle. Emulsion exposed 30 days. ×1000. Stripping method.

Fig. 5. Photograph of pearl-oyster mantle. ×1.

Fig. 6. Radioautograph of pearl-oyster mantle of Fig. 5. Heavy deposits of Ca^{45} appear all over the mantle and especially in the periphery. Emulsion exposed 180 days. ×1. Contact method.

Fig. 7. Radioautograph of a section of pearl sac in pearl-oyster. Localization of P^{32} is shown by blackened epithelial areas (lower part) and conchiolin layer of pearl (upper string). ×200. Stripping method.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Studies on the Fish Fauna at the Southern Vicinity of Tsu City, Mie Prefecture

(*With 2 Plates, 1 Figure and 3 Tables*)

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Since 1952 intensive collecting has been done in brackish and tidal fresh waters of the down stream of the Ai-Kawa and its branches, and numerous collections have been made at the several stations of fresh water regions. The Ai-Kawa is a complicated small stream flowing into the Ise Bay, and run the southern vicinity of Tsu City, Mie Prefecture.

The study of fish fauna in a small estuary and its upper streams is a difficult work in consequence of following causatives: seasonal or tidal migration, unexpected visit from open sea or upper streams, sudden change or environmental factors such as water temperature or transparency, abnormal ascending or descending based upon the peculior conditions such as invasion of reddish brown tide, inflow or poisonous substances or cure of diseases. The tides move the water up and down, so that at a given location the population at low tide may be quite different from that present at high tide. In addition to the obvious tidal movements, the waters are formed of masses or layers with difference of the specific gravity by salt concentration of itself.

Collections were made from February to December, but the most intensive collecting was done during the summer. The several thousand samples included 27 families, 48 genera and 56 species, were collected by a fishing net specially designed by our own idea, a four armed drop net, a casting net, an angling and other methods.

Description of Area Studied

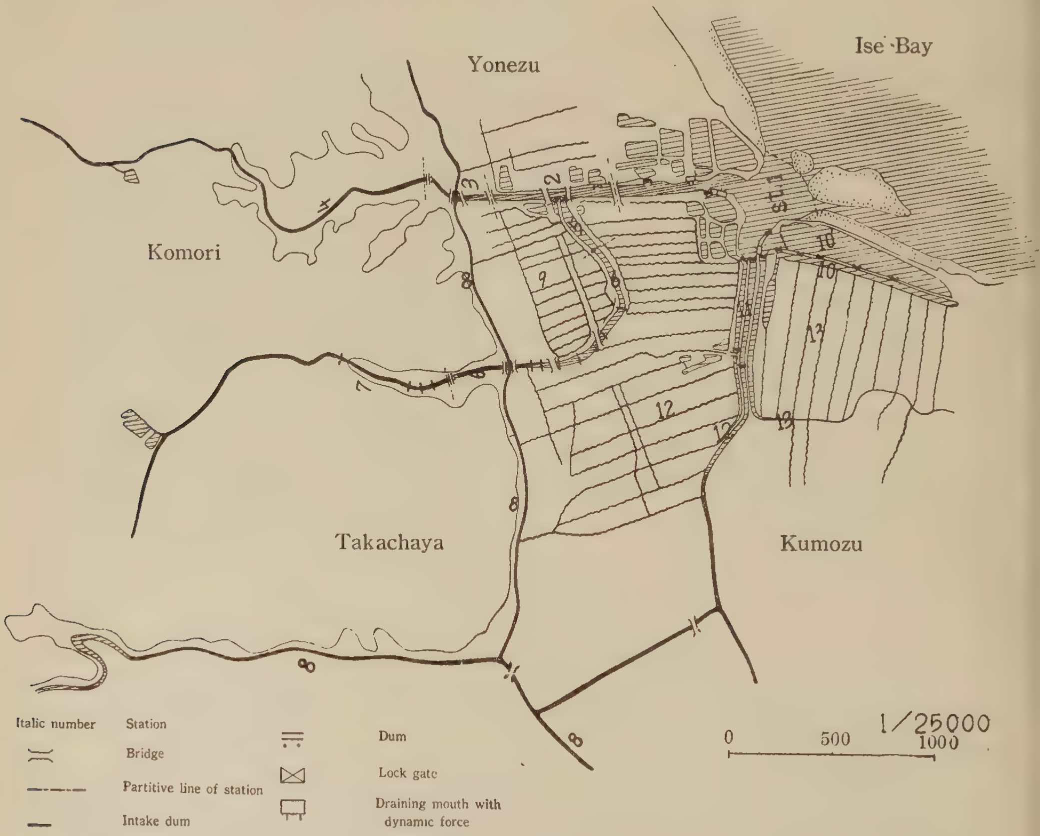
In this area, the general situations of water system are as follows (Text-fig. 1):

1) The Ai-Kawa, ca. 8.5 km. in total length, the brackish region is clearly partitioned from fresh water by dum (Fig. 7), ca. 1.8 km. in length. The stream mouth has an inlet so-called the "Sengan" which joints of the draining way of irrigation water through the lock gate at this point (Figs. 1 and 2). The majority of draining ways (creeks) which joint or lie at both side of stream, hold two purposes of the fish pond and the protection of tidal injury also.

2) The Tenjin-Gawa, ca. 4.1 km. in total length, which is a branch borded by lock gate from the Ai-Kawa, has a brackish region partitioned on intake dum with sheeting, ca. 400 m. in length. In the mid-stream, this water is completely divided into two parts by dum (Fig. 6).

3) The "Sengan" Water System is composed with several draining ways (creeks), fish ponds and numerous irrigation ditches which are originated from the Kumozu Irrigation Water Way (Figs. 2, 4 and 8.)

4) The Kumozu Irrigation Water Way is inducted from the Kumozu River at Heki Village, Itsushi District. The overflowing water in this way is follen into the fresh water region of the Tenjin-Gawa (Fig. 5) and into brackish region of the Ai-Kawa. But this way is interrupted from the last decade of November to the first part of May in each year, therefore, during the winter season the irrigation ditches, rice fields or draining ways (fish ponds) near the brackish or sea display of salt infiltration on farm soil or dead water in comparison with another region or other season at same place.



Text-fig. 1. Showing the general situation of water system at the southern vecinity of Tsu City.

For convenience in summarizing the data, the water regions in this area were divided into thirteen stations and one sub-station by lock gate, dum, bridge,

Table 1. Situations of Water Region and Occur

Station number	I			II	III	IV	V
Stream or place name, and its circumstance	estuary sf the Ai-Kawa			the Ai-Kawa			
	"Sengan"		stream near the estuary	mid-portion of brackish region	up-portion of brackish region	fresh water region	brackish region
Bottom type	sand; small stone; mud; stone monument	sand; mud; stone monument	sand; mud; stone monument; muck	sand; mud; small stone; muck	sand; mud; small stone; muck; detritus	sand; mud; small stone; muck; detritus; rockery; silt	mud; mu silt
Bank or edge of water region	bank of concreat and stone monument					concreat; stone monument; cliff; bush and soil	concreat stone monumen
Summer, at low tide (lowest, 14.55): date (June 28, '56)	14.55	15.10	14.43	14.30	14.15	14.20	16.38
Summer, at low tide: temperature (°C, water surface)	28	26	27	26	25	24	25
Summer, at low tide: Cl′ (g/L) surface	1.27	3.57	2.72	0.89	0.048	0.040	0.30
Summer, at low tide: Cl′ (g/L) bottom	12.99	3.64	2.77	0.99	0.052		
Summer, at high tide (highest, 21.20): date (June 28, '56)	23.00	21.23	21.40	22.15	22.35		9.30 (June 2
Summer, at high tide: Cl′ (g/L) surface	11.25	4.34	1.44	0.234	0.207		0.11
Summer, at high tide: Cl′ (g/L) bottom	13.07	12.38	12.63	10.26	2.65		7.77
Balanus amphitite albicostatus, and its survival limit	++	+++	+++	++ - ı	± - − 10 m. up-stream of bridge of state railway	−	± − 2 m. up-stream o lock gat
Ostrea gigas, and its survival limit	++++	++++	++++	+++ − +	+ − − same as the above	−	± − same as above
Exosheloma sp., in summer, (first decade of June 1956)	+++	++++	+++	+++ − +	± − −	−	± −
Exosheloma sp., in winter, (last decade of Feb. 1956)	++++	++++	++++	++++ − ++	++ − −	−	+++ −
Tylorrhynchus heterocheatus	+++	+++	+++	++++	++++ − ±	−	++++ −
Enteromorpha sp., in first decade of May 1956	+	±	+	+	±	−	−
Ulva pertusa, in mid-decade of June 1956	+	+	+	+	+ − −	−	−

of Marine or Brackish Organisms in this Area.

VI	VII	VIII	IX	X	X′	XI	XII	XIII
he Tenjin-Gawa		the Kumozu irrigation water way	irrigation ditches and rice fields	the "Sengan" Water System				
fresh water region	upper stream			draining creek (fish pond) and irrigation ditches	fish pond	draining creek and fish pond	draining creek (fish pond), culture ponds and irrigation ditches	draining or supplying water way, and irrigation ditches
mud; muck; small stone; detritus; rockery	mud; muck; stone; detritus; silt	mud; sand; detritus; concreat; small stone	mum; muck; silt	mud; sand; silt; stone	sand; mud; stone	sand; mud; stone	mud; muck; silt; sand	mud; muck; silt
concreat; stone monument; cliff; bush and soil	soil; bush; stone monument; concreat	concreat; soil; stone monument	soil	soil; stone monument; concreat	soil; stone monument concreat	concreat; soil; stone monument	concreat; soil; stone monument	soil stone monument
16.45	17.00	16.54	a 16.37 b 16.39	a 16.05 b 15.42	a 15.52 b 15.20	15.03	16.20	16.25
24	22	23	a 26 b 26	a 26 b 26	a 25 b 26	26	27	29
0.014	0.016	0.012	a 0.154 b 0.052	a 0.73 b 2.36	a 5.43 b 0.83	0.554	0.047	0.051
				a 0.85 b 2.77	a 5.86 b 5.68	0.644		0.057
					b 21.10	22.55	10.05 (June 29)	
					b 0.436	1.29	0.079	
					b 9.19	9.66	0.88	
–	–	–	–	–	+++ – – 15 m. upper of lock gate	++ – – 20 m. upper of lock gate	–	–
–	–	–	–	–	++++ – – 20 m. upper of lock gate	++ – – 45 m. upper of lock gate	–	–
–	–	–	–	+ – –	+++ – ±	++ – –	–	–
–	–	–	–	+++ – +	++++ – ++	+++ – +	+ – –	+ – –
± – –	–	–	± – –	++++ – ++	+++ – +	++++ – ++	+++ – ±	++ – ±
–	–	–	+++ in fish pond	+++ – –	+++ – –	+ – –	–	–
–	–	–	± in fish pond	± – –	+ – –	+ – –	–	–

shoal or others, and all collections in each station were lumpted (Table 2). The general situations in each station are shown in Table 1. In addition to the environmental factors such as chlorinity, water temperature, bottom type and etc., the biological certifications of salt concentration in brackish regions were able to be shown by distribution limit of marine or brackish organisms as follows: *Balanus amphitite albicostatus*, sessile *Crustacea*; *Ostrea gigas*, sessile *Bivalvia*;

Table 2. Occurrence of Fishes in each Station.

Station / Fish Name	I	II	III	IV	V	VI	VII	VIII	IX	X	X′	XI	XII	XIII
Konosirus punctatus										±	+			
Atherina bleekeri	+	±									±			
Plecoglossus altivelis	+	±												
Plotosus anguillaris	±													
Parasilurus asotus		±	±	+		+	+	+	+	+	±	+	+	+
Carassius auratus	±	+	+	+	±	+	+	+	+	+	+	+	+	+
Cyprinus carpio						±								
Gnathopogon elongatus elongatus						±		+	+				±	+
Pseudorasbora parva sub. sp.						+		+	+					
Acheilongnathus lanceolata				+		+		+	+					
Hemibarbus barbus				+		±				+			+	+
Sarcocheilichthys variegatus						±								
Pseudogobio esocinus			±	+		+		+						
Zacco teminckii			±	±	±	+		+	+					±
Zacco platypus			+	+	±	+		+	+				±	±
Tribolodon hakuensis	+									+	±		±	+
Hemigrammocypris rasborella				+		+		+	+				±	±
Misgurunus anguillicaudatus		±	±	+	±	+	+	+	+	+			+	+
Cobitis biwae				+		+	+	+	±					
Cobitis delicata						±		±						
Olyzias latipes	±	±	+	+	+	+	+	+	+	+	±	±	+	+
Anguilla japonica	+	+	+	+	+	+	±	+	+	+	+	+	+	+
Anguilla mauritiana	+	+	+	+	+	+	±	+	+	+	+	+	+	+
Astroconger myriaster	+										+			
Hemirhamphus kurumeus	+	+	±							+	+	+	±	
Mugil cephalus	+	+	+		±	±				+	+	+	+	+
Leiognathus nuchalis	±													
Chana argus				±		±		+	+	+				
Lateolabrax japonicus	+	+	+		±	±			±	+	+	+	+	±
Therapon oxyrhynchus	+										±			
Therapon jarbus	+	+	+		±					±	+	+	+	
Milio macrocephalus	+	+	±							±	+	±		
Siganus fuscescens	±													
Sillago shihama	+													
Fugu niphobles	+													

Table 2. (Continued)

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	X′	XI	XII	XIII
Hexagrammos otakii	±													
Cottus pollux						±		±						
Platycephalus indicus	+	±								±	±			
Suggurundus meerdervoorti		±												
Mogurunda obscura		±		+						±			+	+
Acanthogobius flavimanus	+	+	+		+	+			±	+	+	+	+	+
Chaenogobius annularis annularis	+	+	+		+					+	+	+	+	+
Tridentiger obscurus	+	+	+		+	+			+	+	+	+	+	+
Tridentiger trigonocephalus	+										±			
Gobius abei	±													
Gobius similis						±		±						
Gobius gymnauchen	+	±									±			
Eutaeniichthys gilli	+													
Glossogobius giuris brunneus	+	+	±							+	+	+		
Periophthalmus cantonensis	+	±												
Kareius bicoloratus	+	+	±		±					±	+	+	±	
Limanda herzensteini	+	±									+			
Callionymus lunatus	+	±									±			
Enedrias nebulosus	+													
Dasson elegans	+	±									±			
Dasson trossulus	+	±									+			
Common collections	29	13	11	13	6	16	5	15	14	16	15	13	15	14
Rare collections	7	14	8	2	8	9	2	3	3	6	12	2	6	5
Total	36	27	19	15	14	25	7	18	17	22	27	15	21	19

Exospheloma sp., swimming *Crustacea*; *Tylorrhynchus heterocheatus*, *Annelida*; *Enteromorpha* sp., and *Ulva pertusa*, *Algae*.

Water temperature in the region which gets no influence of salt water, is remarkably varied by the atmospheric temperature and the weather on that occasion because of the little volume of waters and of the slight depth seen in such streams. Therefore, the water temperature of the stream observed is very low in winter and very high in summer.

The determination of chlorine concentration in each station was tried on the waters of surface or bottom at low and high tides by Mohr-Knudsen's method.

From the Table 1, the Stations IV, VI to VIII, or a part of IX, XII and XIII are beyond all manner of doubt about the fresh waters during the year, and the other stations have a brackish or its tendency with the conditions of season or tide.

In the last few years, the fish fauna in this area is changing with the influences of consequences of conservancy or agricultural chemicals. Therefore, the descriptions on circumstances at each station in Table 1 are done on the conditions of both years, 1955 and 1956.

Annotated List of Fishes

1) *Konosirus punctatus* (TEMMINCK et SCHLEGEL), "Konoshiro,"—marine fish—*cf.* (*3*) *p. 42, fig. 41.* The land-locked adult specimens were rarely captured in brackish fish ponds at Stations X and X′, but this species was almost impossible to be discovered from the other regions in this area. The course or source of the fish in these ponds which are land-locked from open brackish regions by a bamboo-blind or bank, is yet unknown.

2) *Atherina bleekeri* (GÜNTHER), "Tôgorô-Iwashi," "Neko-Kuwazu"=local name,—marine fish—. Many numbers of this fish were collected in estuary and stream mouth so-called the "Sengan" in summer night at high tide, 1954 and 1956. They swim on water surface forming the school with several individuals, and go away from estuary to the Ise Bay at low tide.

3) *Plecoglossus altivelis* (TEMMINCK et SCHLEGEL), "Ayu,"—anadromous fish—*cf.* (*6*) *p. 142, fig. 59.* Generally speaking a fresh water species, a few normal and diseased (dermatological) young specimens were collected in stream mouth and Station II, April 1954, March 1955, and April 1956. Young "Ayu" make a circular (migrating) swimming among the salt and brackish waters from February to June, but they not ascend the stream here.

4) *Plotosus anguillaris* (FORSKÅL), Sea cat-fish, "Gonzui,"—marine fish—*cf.* (*3*) *p. 68, fig. 64.* Few specimens were rarely captured in stream mouth near the sea at high tide of summer night, July 1953. Since then, we have not seen the sea cat-fish in this region.

5) *Parasilurus asotus* (LINNÉ), Muddy cat-fish, "Namazu,"—fresh water fish~*cf.* (*2*) *p. 53, fig. 33.* Many were commonly captured from all regions of fresh water at night, May to November in each year, but the several individuals were occasionally taken from tidal brackish waters, and even from brackish regions at high tide. We observed spawing of them in irrigation ditches (Station XII), July 1954.

6) *Carassius auratus* (LINNÉ), Cruscian carp, "Funa,"—fresh water fish—*cf.* (*3*) *p. 72, fig. 68.* Found in all fresh water regions, the adult specimens were most commonly taken by angling. This fish was abundantly collected in low brackish waters, but was not abundant in brackish regions nearer the stream mouth. They which came floating away to the outer side of lock-gate by the current of low tide, were often dull in swimming behaviors with the sudden change of the salt concentration of water at high tide. In winter season, when the water get cold and brackished, they living in its environment have migrated to the deeper water of fresh regions. It is possible that the fish sometimes spawns in lower brackish region similar to the case of fresh waters from May to June.

7) *Cyprinus carpio* (LINNÉ), Carp, "Koi,"—fresh water fish—*cf.* (*3*) *.d 74, fig. 69.* A young specimen was obtained in Station VI (Tenjin-Gawa), September 1955. It seems to be distributed here from the Kumozu River pass through the Kumozu Irrigation Water Way. This fish was not yet discovered at the other stations in this area.

8) *Gnathopogon elongatus elongatus* (TEMMINCK et SCHLEGEL), "Ta-Moroko,"—fresh water fish—*cf.* (*3*) *p. 75, fig. 70.* The several specimens were collected in the irrigation ditches of level land. This fish was not taken from low brackish regions, e.g., Stations V, X, XI, and a part of XII and XIII.

9) *Pseudorasbora parva* sub-sp., a kind of "Motsugo," "Yanagi-Moroko"=local name,—fresh water fish—Pl. II, Fig. 9a. This specimen is impossible to identify as *P. parva parva* (TEMMINCK et SCHLEGEL) with the differences of proportional characters and the imperfection of lateral line series (Pl. II, Fig. 9a and b), and as *P. parva pumila* (MIYADI) with the scale numbers and the proportional characters. We are investigating the taxonomical position and varieties of them. Several individuals were obtained in fresh waters of down stream of the Tenjin-Gawa and irrigation ditches up to the autumn of 1953. Since then, this fish was almost impossible to be collected as the confines of highest tide combined with the typhoon No. 13, 1953. In 1956, a single specimen was collected in the Tenjin-Gawa (Station VI).

10) *Acheilognathus lanceolata* (TEMMINCK et SCHLEGEL), "Yari-Tanago,"—fresh water fish—*cf.* (*3*) *p. 80*, *fig. 75*. Commonly found in fresh waters they never inhabit in brackish regions. The adult specimens were abundantly collected in the fresh water of the Ai-Kawa. They which were spawning into mantle cavity of a small musseles, *Inversidens japanensis* (LEA), through a long ovipositor, and hatched in the same cavity, were observed by ourselves.

11) *Hemibarbus barbus* (TEMMINCK et SCHLEGEL), "Ni-Goi," "Mizu-Goi"=local name, —fresh water fish—*cf.* (*3*) *p. 85*, *fig. 80*. A young specimen was seined in fresh water region (Station VI) of the Tenjin-Gawa, September 1955. Since then, several youngs were collected in Ai-Kawa (Stations III and IV) and in irrigation creeks (Station X).

12) *Sarcocheilichthys variegatus* (TEMMINCK et SCHLEGEL), "Higai,"—fresh water fish—*cf.* (*6*) *p. 164*, *fig. 85*. A young fish was collected at Station VI of the Tenjin-Gawa, September 1955. Up to the present, this species was not described from the south of the Middle Ise inclusive of this area. Generally considered an exotic species, it was introduced from the Lake Biwa, Shiga Prefecture, to the Kumozu River as the impurities of stocked young "Ayu,„ and was found to pass here through the Kumozu Irrigation Water Way.

13) *Pseudogobio esocinus* (TEMMINCK et SCHLEGEL), "Kamatsuka,"—fresh water fish —*cf.* (*6*) *p. 164*, *fig. 86*. Many young fish were common in the fresh waters of down stream from the dum of the Tenjin-Gawa and of upper stream from one of the Ai-Kawa, and in the Kumozu Irrigation Water Way. A few young specimen were collected by small fishing net in tidal low brackish water at directly beneath of the dum of the Ai-Kawa. But we have not observed them here at high tide. The survival in that condition might be next to be impossible for them. The adults were rarely taken from the upper stream of the Ai-Kawa, but they were not obtained in another region.

14) *Zacco temminckii* (TEMMINCK et SCHLEGEL), "Kawamutsu,"—fresh water fish—*cf.* (*3*) *p. 90*, *fig. 85*. Several numbers of young fish were taken in the irrigation ditches, fresh water regions of down stream from the dum of the Tenjin-Gawa and the Kumozu Irrigation Water Way, June to November, but the adults were comparatively rare. The young fish were often observed from the tidal fresh waters. This species is not yet collected in the upper stream of dum of the Tenjin-Gawa.

15) *Zacco platypus* (TEMMINCK et SCHLEGEL), Common minnow, "Oikawa," "Shira-Haya"=local name,—fresh water fish—*cf.* (*3*) *p. 91*, *fig. 86*. This species swims the stream in schools intermingling with *Z. temminckii*. They were abundantly captured than above species, and were distributed in the same to it, but their adaptability for brackish water seem to be shown the wide range than it. For instance, the many specimens were collected on the water surface ($Cl'=0.207$) of tidal region (Station III) at high tide, June 1956.

16) *Tribolodon hakuensis* (GÜNTHER), "Ugui,"—fresh water or descending fish—*cf.* (*3*) *p. 93*, *fig. 88*. We have captured the small numbers of adult specimen which have ascended from the Ise Bay to brackish region in April 1955, and which have descended from upper streams to estuary, October to November 1955. The young specimens were collected by small fishing net in stream mouth at low tide, June to July. Genus *Tribolodon* is known to be the only genus of the family *Cyprinidae* that normally inhabitats in sea water.

17) *Hemigrammocypris rasborella* (FOWLER), "Kawabata-Moroko,"—fresh water fish —*cf.* (*6*) *p. 175*, *fig. 53*. The numerous specimens were only collected in fresh waters of irrigation ditches, rice fields and small ponds of level land. This species was not found even in tidal fresh water of lower chlorinity.

18) *Misgurunus anguillicaudatus* (CANTOR), Loach, "Dojyo,"—fresh water fish—*cf.* (*3*) *p. 89*, *fig. 94*. Numerous in whole regions of fresh water, many loaches were captured even from the tidal fresh waters such as Stations III, V, IX, X, XII and XIII. They were abundant in rice fields, irrigation ditches, streams and dead waters, and some were taken by a conical fish trap.

19) *Cobitis biwae* (JORDAN et SNYDER), "Shima-Dojyo,"—fresh water fish—*cf.* (*3*) *p.*

95, fig. 90. Several specimens were taken in fresh waters which had a lower temperature, swifter current and higher transparency in comparison with a habitat of common loach. They were not observed in tidal fresh waters which had a higher temperature and dull current such as irrigation ditches, rice fields or other dead waters. They were abundant in Stations IV (inclusive of Hisai-Town, Itsushi District), VI, VII and a part of VIII.

20) *Cobitis delicata* (NIWA), "Ajime-Dojyo,"—fresh water fish—*cf.* (6) *p. 186, fig. 114.* Generally considered a swift (mountain) torrent fish, two specimens were only collected at Station VI in the Tenjin-Gawa, July 1954, and at Station VIII in the Kumozu Irrigation Water Way, September 1955. They seem to be come here from the Kumozu River. This species is not yet discovered in the other regions of this area.

21) *Olyzias latipes* (TEMMINCK et SCHLEGEL), "Medaka,"—fresh water fish—*cf.* (2) *p. 268, fig. 91.* Most commonly found in irrigation ditches, rice fields, ponds, streams and creeks in this area, they were abundantly collected in whole regions of fresh water during the year, and were often taken even in tidal brackish. Small specimens were observed on the water surface of brackish regions near the sea, but their behaviors were dull in swimming.

22) *Anguilla japonica* (TEMMINCK et SCHLEGEL), Japanese eel, "Unagi,"—catadromous fish—*cf.* (6) *p. 187, fig. 116.* The eels have abundantly inhabited in whole regions of this area. They were cultured in fish ponds as a chief aquatic product in this area. Many adults have been captured by bamboo-pipe, eel trap, eel stone monument or others from April to November. The *elva* ascending the stream in schools were captured by silk or nylon nets under the acetylene light, usually during the night at low tide, February to May. The young eels so-called "Hari-Unagi" were taken by the same method from May to July. In the daytime, the *elva* and "Hari-Unagi" in estuary or brackish regions have inhabited into the living-hole of a shell fish (*Miya arenalia*) and a shrimp (*Upogebia major*), an interspace of eel stone monument, and under such deposites as stone, shell, algae, wood-piece lying on bottoms. The adult eels on the approach of majority have descended the stream towards the sea, August to December.

23) *Anguilla mauritiana* (BENNETT), "Kanikui,"—catadromous fish—. This species is distinguishable from *A. japonica* with short snout. They have been intermingled with *A. japonica* in their distributions. Numerous specimens were captured in whole regions at night, spring to autumn.

24) *Astroconger myriaster* (BREVOORT), Common Japanese conger, "Ma-Anago,"—marine fish—*cf.* (3) *p. 112, fig. 97.* This conger was rarely collected in brackish pond at Station X′, but the majority of fish captured was taken by bamboo-pipe in estuary or its out-side, April to August.

25) *Hemirhamphus kurumeus* (JORDAN et SNYDER), "Kurume-Sayori,"—marine and brackish water fish—*cf.* (6) *p. 190, fig. 73.* Several adult specimens were collected on the water surface of estuary, and a part of them which were migrated from the Ise Bay, were rarely taken even from the draining creeks and fish ponds of low brackish or fresh waters, summer to autumn.

26) *Mugil cephalus* (LINNÉ), True mullet, "Bora,"—marine and brackish water fish—*cf.* (6) *p. 191, fig. 121.* This mullet has names depending in size as follows: "Haku," 4.0 cm. or less in length; "Oboko," "Inakko" or "Subashiri," 3.0 to 18.0 cm.; "Ina," 15.0 to 35.0 cm.; "Bora" = adult name, longer than 30.0 cm.; "Todo," same to "Bora" in length, but very high in depth. These names in size have been varied by localities.

The numerous young specimens, so-called "Haku," which came up from the open sea into the brackish waters of estuary for ascending the stream, were captured by a four armed drop-net of a scoop-net at low tide, March to May (or June). A part of them were already observed inhabiting in the fresh water regions of irrigation ditches on April. They which grow to 15.0 cm. or more in length from October to November of the first year, return to the sea. But the land-locked fish were able to be cultured in a brackish pond near the fresh water during the year with no apparent ill effects. This mullet is important

as the cultured fish of natural ponds or the "Uki-Uo" which is a mingling fish in eel ponds of this area.

27) *Leiognathus nucharis* (TEMMINCK et SCHLEGEL), "Hiiragi," "Zeme or Zenme"= local name,—marine fish—. Small numbers of adult specimens were taken in the "Sengan" of estuary at low tide, July 1953. We have not yet collected this fish in another station.

28) *Chana argus* (CANTOR), "Kamuruchi,"—fresh water fish—*cf.* (*6*) *p. 192, fig. 122.* This species is a naturalized fish (from Korea) which has gradually trepassed from Yokkaichi City into this area at the last few years. In Mie Prefecture, at present, the southern limit or their distribution is Matsusaka City or its neighborhood. The specimens have distributed in whole regions of fresh or low blackish waters. But they which live into low blackish waters during the temperate season, the majority have been dead there on account of the natural increase of salt concentration in the habitat, and it is based upon the suspension of the supplying and draining of irrigation waters in cold season of each year.

29) *Lateolaborax japonicus* (CUVIER et VALENCIENNES), "Suzuki,"—marine fish—*cf.* (*3*) *p. 191, fig. 175.* This fish has various names by a degree of growth as follows: "Seigo," young name; "Mataka" or "Fukko," larger than 30.0 cm. in length; "Suzuki," adult name, larger than 60.0 cm. These names by growth have been varied by localities.

The young specimens were very abundantly captured in whole brackish regions, April to November. When 1.0 to 6.0 cm. in length, they have migrated from the Ise Bay into the brackish water of estuary in Schools, they grow to be of a larger than 10.0 cm., before returning to the sea from September to November of the first year. They have a strong adaptability for fresh water. The two specimens shown each ca 20 cm. long were captured from fresh water region (Station VI) which were completely land-locked with four intake dums and one lock gate, but did not reveal any abnormality in conditions and behaviors. The "Suzuki" and "Mataka" were often found migrating to the "Sengan" for fooding the small fishes flood from lock gate by current at low tide of summer night.

30) *Therapon oxyrhynchus* (TEMMINCK et SCHLEGEL), "Shima-Isaki," "Sumihiki"= local name,—marine fish—*cf.* (*3*) *p. 222, fig. 205.* For young specimens were collected in stream mouth, July to October. But the adult specimen was not discovered in whole regions of brackish water.

31) *Therapon jarbua* (FORSKÅL), "Yagata-Isaki,"—marine and brackish water fish—*cf.* (*3*) *p. 223, fig. 206.* Usually the adults live in the sea water, but the young specimens commonly fish in the estuary and often ascend the stream from July to October. Young specimens were obtained in the "Sengan" and its neighbourhood (Stations X, X′ XI and XII), but was not taken in the Ai-Kawa (Stations II and III). The adults have been rarely collected in brackish fish ponds.

32) *Milio macrocephalus* (BASILEWSKY), "Kuro-Dai," "Kaizu"=local name,—marine fish—*cf.* (*3*) *p. 232, fig. 214.* The "Kuro-Dai" were sometimes seen in the estuary forming a school. The young specimens were commonly taken by angling in the "Sengan" or brackish fish ponds from June to October, and were rarely captured even in low brackish waters near the fresh (Station X).

33) *Siganus fuscescens* (HOUTTUYN), "Aigo," "Aei"=local name,—marine fish—*cf.* (*3*) *p. 288, fig. 260.* Small numbers of young fish were taken in brackish water near the sea. But this species was not discovered without that region.

34) *Sillago sihama* (FORSKÅL), "Kisu,"—marine fish—*cf.* (*3*) *p. 256, fig. 234.* The specimens have been occasionally collected in the stream mouth on its outside at high tide when a continuance of fine weather, June to September. Although they were more abundant near the sea, a single specimen was collected also in tidal brackish water of the "Sengan," June 1956.

35) *Fugu niphobles* (JORDAN et SNYDER), "Kusa-Fugu,"—marine fish—*cf.* (*3*) *p. 300, fig. 269.* The two specimens were obtained in tidal brackish region at the "Sengan" at low tide, July 1953 and June 1956, but one individual was unable to identify for incomplete

fixation. From the observation in outside of estuary, they were lain into the bottom by reason of salt decrease at low tide, and were swimming at high tide.

36) *Hexagrammos otakii* (JORDAN et STARKS), "Ainame,"—marine fish—*cf.* (3) *p. 330, fig. 298.* A single specimen which was measured 25.0 cm. in total length, was obtained in the "Sengan" at high tide, March 1956.

37) *Cottus pollux* (GÜNTHER), "Kajika,"—fresh water fresh—*cf.* (6) *p. 335, fig. 303.* Small numbers of "Kajika" were rarely taken in the fresh waters of the Tenjin-Gawa (Station VI) and of the Kumozu Irrigation Water Way during the summer. It seems to be distributed here from the Kumozu River which is a inhabitat of them. But in this area, they were very scarcely populated.

38) *Platycephalus indicus* (LINNÉ), "Kochi,"—marine fish—*cf.* (3) *p. 343, fig. 311.* The flat head fish were often captured by a fish-spear or net under the acetylene light at high tide of summer night. They have occasionally lain on sand bottom of the foot of eel stone monuments at the stream mouth. The two specimens were taken in the fish pond (Station X) of low brackish waters land-locked with banks in May 1956.

39) *Suggrundus meerdervoorti* (BLEEKER), "Megochi,"—marine fish—A single specimen was only taken from Station II, October 1955.

40) *Mogurunda obscura* (TEMMINCK et SCHLEGEL), "Donko,"—fresh water fish—*cf.* (6) *p. 201, fig. 133.* Small numbers were collected in upper stream the dum of the Ai-Kawa. Generally considered a fresh water goby, but a single specimen was taken in tidal brackish region (Station II), September 1953.

41) *Acanthogobius flavimanus* (TEMMINCK et SCHLEGEL), "Ma-Haze,"—brackish water fish—*cf.* (6) *p. 204, fig. 138.* This goby lives in estuary or its outside, and occasionally ascends the stream. They were most commonly collected from whole brackish regions of this area from May to November, but were never recognizable the inhabitance in the upper stream from the dums of both streams and in the Kumozu Irrigation Water Way.

42) *Chaenogobius annularis annularis* (GILL), "Biringo,"—brackish water fish *cf.* (6) *p. 204, fig. 139.* This goby was commonly collected in whole brackish regions, and was often found in fresh waters also. They were able to be discriminated by swimming the mid-layer from the other gobies.

43) *Tridentiger obscurus* (TEMMINCK et SCHLEGEL), "Chichibu,"—brackish water fish —*cf.* (3) *p. 368, fig. 335.* Although the specimens were most abundant in the brackish waters, a few were found in fresh waters of both streams. They which were collected in blackish water were maintained in fresh water pond for a period of several years with no apparent ill effects, and were bred there. On their adaptability for salt or fresh waters, we have alreadly reported in 1956. They spawn the eggs in the oyster shell and etc. from April to June in brackish region, and May to September in fresh region.

44) *Tridentiger trigonocephalus* (GILL), "Shima-Haze"—brackish water fish—*cf.* (6) *p. 207, fig. 143.* Few specimens which were taken in stream mouth, were not collected in other regions.

45) *Gobius abei* JORDAN et SNYDER, "Abe-Haze,"—brackish water fish—*cf.* (6) *p. 203, fig. 136.* An adult specimen was taken in stream mouth (Station I) at low tide, July 1956.

46) *Gobius similis* (GILL, JORDAN et SNYDER), "Yoshinobori,"—fresh water fish—*cf.* (6) *p. 202, fig. 88.* The two specimens were obtained in Stations VI and VIII, July 1954, and it was not discovered from other regions in this area These both specimens should be considered that they here come up from the Kumozu River.

47) *Gobius gymnauchen* (BLEEKER), "Hime-Haze,"—brackish water fish—*cf.* (2) *p. 342, fig. 291.* Small numbers of "Hime-Haze" were taken in brackish water near the sea. A single specimen was collected in low brackish region (Station X′) in May 1956. This species is a new collection in this Prefecture.

48) *Eutaeniichthys gilli* JORDAN et SNYDER, "Himo-Haze,"—brackish water fish— This gobioid fish was often collected from the living hole of a shrimp, *Upogebia major*, in estuary bottom. This species has never been found in this prefecture,

49) *Glossogobius giuris brunneus* (TEMMINCK et SCHLEGEL), "Uro-Haze," "Ishi-Haze" or "Dobu-Haze"=local name,—brackish water fish—Pl. II, Fig. 10. Many adults were commonly captured in whole brackish regions, but they were not obtained in fresh waters. This species too is a new collection in this Prefecture.

50) *Periophthalmus cantonensis* (OSBECK), "Tobi-Haze,"—brackish water fish—Many specimens were collected on the sandy bottom of stream month exposured at low tide.

51) *Kareius bicoloratus* (BASILEWSKY), "Ishi-Garei,"—marine fish—*cf.* (*3*) *p. 390, fig. 351.* Many in whole brackish regions, young specimens were numerously taken in the estuary near the sea. The adults were rarely captured in the "Sengan" and brackish fish ponds. By the opinion of a fish culturist, this species was not maintained in fresh or low brackish waters (irrigation creeks and etc.) during the summer with ill effects.

52) *Limanda herzensteini* (JORDAN et SNYDER), "Ma-Garei,"—marine fish—. Small specimens were taken intermingling into the "Ishi-Garei" in the brackish region of estuary at low tide, but the adult was not obtained.

53) *Callionymus lunatus* (TEMMINCK et SCHLEGEL), "Numeri-Gochi,"—marine fish—*cf.* (*3*) *p. 404, fig. 363.* The fish were abundantly taken in the outside of estuary, May to October. But they were rarely collected even in tidal brackish regions at Stations I, II and X′ at high tide.

54) *Enedrias nebulosus* (TEMMINCK et SCHLEGEL), "Ginpo," "Ginbo"=local name,—marine fish—*cf.* (*3*) *p. 415, fig. 374.* Several numbers of young fish were collected from muddy bottom cespitosed of the "Ajimo," , in brackish regions near the sea, May to September.

55) *Dasson elegans* (STEINDACHNERI), "Nabeka,"—marine fish—*cf.* (*2*) *p. 382, fig. 345.* They were collected from the quay wall or the interspace of eel stone monument in the Stations I, II and X′ near I.

56) *Dasson trossulus* (JORDAN et SNYDER), "Niji-Ginpo,"—marine fish—*cf.* (*2*) *p. 382, fig. 346.* A few adult specimen were collected at the "Sengan" during the summer, but the young was not obtained. This species is a new collection in this Prefecture.

Conclusions and Summary

1) A preliminary investigation of the fish fauna was made on brackish and fresh water regions which were divided into thirteen stations and one sub-station, at the southern vicinity of Tsu City, Mie Prefecture, Japan, 1952 to 1956.

2) The general situations of water system and each station were described, and as a part of environmental factors, the consideration dealing to salt concentration of waters was shown by distribution limit of marine or brackish organisms also.

3) For convenience in summarizing the data, all collections of fishes and general situations in each station were rumped. Several interesting observations were made regarding the habitat adaptability of fishes in natural condition. The investigations were done as to qualititative components of the fish population rather than quantitative of its. And the observations of the fauna were more minutely divided into adaptable habitat for fresh or brackish waters.

4) The main factors affecting the distribution are tidal movements, partitive dums, and ways of water supply or drainage. It seems to be resulted from the data showing in the tables. The transition between salt and fresh waters in

tidal brackish region is abrupt. It is recognizable by floating dusts or difference of transparency with naked eye that the head of tide at high tide forms a remarkable line or water layer with the difference of specific gravity of both waters (fresh and brackish). The regions which were partitioned by lock gate or bank from the sea, estuary or stream, were found an increase or decrease of salt concentration with the infiltration of waters based upon the change of tidal pressures.

5) A total of 27 families, 48 genera and 56 species was found representing the water regions of this area, and only 6 species of fresh water and 10 species of marine are not always possible to be collected here, but the other fishes are found in common. But a recent fauna in fresh waters which include irrigation

Table 3. Nine Categories based upon the Distributions and Adaptabilities for Salt or Fresh Waters of the Fishes in this Area.

Fresh water fish	common	wide adaptability for salt water	I
		none or narrow adaptability for salt water	II
	rare		III
	anadromous or catadromous		IV
Brackish water fish	common	wide adaptability for fresh water	V
		none or narrow adaptability for fresh water	VI
Marine fish		wide adaptability for fresh water	VII
		none or narrow adaptability for fresh water	VIII
	rare		IX

I *Parasilurus asotus*; *Carassius auratus*; *Zacco platypus*; *Misgurunus anguillicaudatus*; *Olyzius latipes*; *Chana argus*; *Mogurunda obscura*.

II *Gnathopogon elongatus*; *Pseudorasbora parva* sub-sp.; *Acheilognathus lanceolata*; *Pseudogobio esocinus*; *Zacco temminckii*; *Hemigrammocypris rasborella*; *Cobitis biwae*.

III *Cyprinus carpio*; *Hemibarbus barbus*; *Sarcocheilichthys variegatus*; *Cobitis delicata*; *Cottus pollux*; *Gobius similis*.

IV *Plecoglossus altivelis*; *Tribolodon hakuensis*; *Anguilla japonica*; *Anguilla mauritiana*.

V *Acanthogobius flavimanus*; *Chaenogobius annularis annularis*; *Tridentiger obscurus*.

VI *Tridentiger trigonocepharus*; *Gobius gymnauchen*; *Glossogobius giuris brunneus*; *Pentonensis*; *Eutaeniichthys gilli*.

VII *Konosirus punctatus*; *Hemirhamphus kurumeus*; *Mugil cephalus*; *Lateolabrax japonicus*; *Therapon jarbua*; *Milio macrocephalus*; *Platycephalus indicus*; *Kareius bicoloratus*.

VIII *Atherina bleekeri*; *Astroconger myriaster*; *Therapon oxyrhynchus*; *Sillago sihama*; *Fugu niphobles*; *Limanda herzensteini*; *Callionymus lunatus*; *Enedrias nebulosus*; *Dasson elegans*; *Dasson trossulus*.

IX *Plotosus anguillaris*; *Leiognatus nuchalis*; *Siganus fuscescens*; *Hexagrammos otakii*; *Suggrundus meerdervoorti*; *Gobius abei*.

ditches, rice fields, irrigation water way and others, is changing with the influences of conservancy or agricultural chemicals such as disinfectant, insecticide and artificial fertilizer.

6) *Pseudorasbora parva* sub-sp. is unable to identify to sub-species which is known in Japan. The four species of marine or brackish fishes, *Gobius gymnauchen* Bleeker, *Glossogobius giuris brunneus* (TEMMINCK et SCHLEGEL), *Dasson trossulus* (JORDAN et SNYDER) and *Eutaeniichthys gilli* JORDAN et SNYDER are new collections in this Prefecture; and *Sarcocheilichthys variegatus* (TEMMINCK et SCHLEGEL) is a new collection in the fresh waters of the south of the Middle Ise inclusive of this area.

7) Some marine or brackish species are able to adapt themselves to life in the case transferred gradually from salt to fresh waters. The majority of fresh water fishes are not able to adjust themselves to survive in low blackish. It is imaginable that the degree of adaptation appearing between these two different environments does not always follow. Therefore, it defines among the same species and age. Upon the adaptability for salt or fresh waters, the fishes distributed in this area may be divided into nine categories as shown in Table III.

References

1) JORDAN D. S. and HUBBS C. L., 1925. Record of Fishes obtained by DARVID STARR JORDAN in Japan, 1922, Mem. Car. Mus., Vol. 10.
2) JORDAN, D. S., TANAKA S. and SNYDER J. O., 1913. A Catologue of the Fishes of Japan, Jour. Coll. Sci. Tokyo Imp. Univ., Vol. 3.
3) OKADA Y., 1955. Fishes of Japan, Tokyo.
4) OKADA Y. and KUBOTA S. S., 1956. On the Adaptability for Salt Solution of a Brackish Goby, *Tridentiger obscurus* T. et S.—I, Bull. Jap. Soc. Sci. Fish., Vol. 21, 1204–1209. (*in Japanese*)
5) OKADA Y. and MATSUBARA K., 1938. Key to the Fishes and Fish-Like Animals of Japan, Tokyo and Osaka. (*in Japanese*)
6) OKADA Y. and NAKAMURA M., 1943. Fresh Water Fishes of Japan, Tokyo. (*in Japanese*)
7) OKADA Y. et al., 1951. Annotated List of Animals and Plants of Mie Prefecture, Japan, Tsu. (*in Japanese*)
8) YAMAMOTO S., 1930. A Partial List of Fishes of Mie Prefecture, Mie Prefecture Office. (*in Japanese*)

Explanation of the Plate XVI

Fig. 1. Station I, commands the estuary from the side of lock gate at the "Sengan" at high tide: the left side of upper part, the Ai-Kawa; the right side of same part, the draining mouth with dynamic force.

Fig. 2. Station I, showing the lock gate at the "Sengan" at high tide, the irrigation creek for drainage and the draining mouth with dynamic force.

Fig. 3. Station II, showing the joining point of the Tenjin-Gawa (left) into the Ai-Kawa (right) at high tide.

Fig. 4. Station X (right) and X′ (left), commanding from the side of the bank of the stream mouth.

Fig. 5. Station VI, showing the flood gate which is drained from the Kumozu Irrigation Water Way (Station VIII) into the Tenjin-Gawa (Station VI, upper and down parts of right side).

Fig. 6. Showing the partitive dum of Stations VI (left) and VII (right) of the Tenjin-Gawa.

Fig. 7. Showing the partitive dum of Stations III (down part, tidal region) and IV (upper part, fresh water region) of the Ai-Kawa at high tide.

Fig. 8. Station VII, showing the collection of young mullet by a casting net.

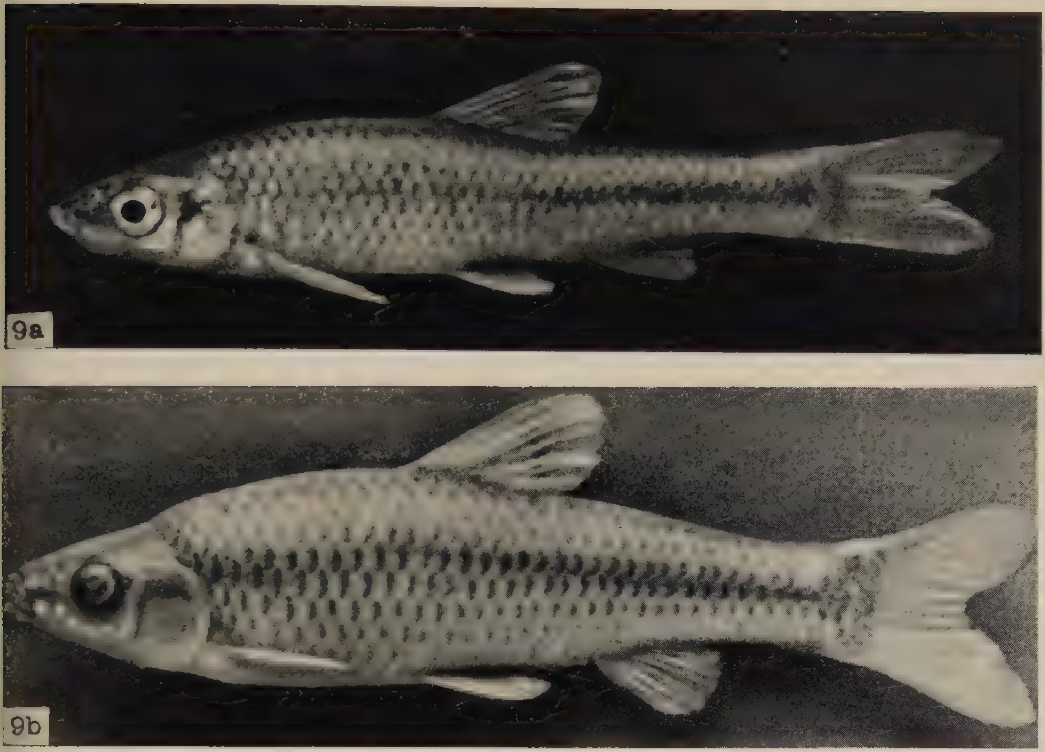


Fig. 9. A comparative photograph between *Pseudorasbora parva* sub-sp. (a) taken in this area and *P. parva parva* (TEMMINCK et SCHLEGEL) (b) collected at the Lake Biwa, Hikone City. ×ca. 2.

Fig. 10. *Glosogobius giuris brunneus* (TEMMINCK et SCHLEGEL) collected in this area. ×ca. 1.

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Ecological Studies of the Ma-anago, *Astroconger myriaster* (BREVOORT)

I. Notes on the composition of total length, the relationship between total length and body weight and the condition factor in Ise Bay, Mie Prefecture

(*With 4 Figures and 4 Tables*)

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The Japanese Ma-anago, *Astroconger myriaster* (BREVOORT) is a valuable edible fish, inhabiting in the waters around Japan. Up to the present no work has been carried out on the ecological aspects of this fish. In the present report, the authors preliminarily dealt with the composition of total length, the relationship between total length and body weight and the condition factor in order to make clear some ecological phenomena of the present species.

Table 1. Showing the average of total length, the growth coefficient and the initial growth index in each material

Locality	Date	No. of individ.	Average of Total length	Growth coefficient	Initial growth index
Toyohama	IV : 24 : '54	104	253.02 mm.	3.44543	−6.93959
	VII : 7 : '54	60	282.54 mm.	3.63389	−7.46467
	VIII : 6 : '54	9	249.44 mm.	3.53815	−7.22469
	X : 3 : '54	94	261.70 mm.	3.11232	−6.23689
	XI : 7 : '54	70	251.14 mm.	3.31851	−6.71064
	I : 15 : '55	124	204.92 mm.	3.15754	−6.24215
	III : 19 : '55	169	238.14 mm.	3.33456	−6.66768
Aritaki	V : 16 : '54	26	295.38 mm.	3.23120	−6.38280
	VI : 19 : '54	57	289.56 mm.	3.74492	−7.66077
	VII : 17 : '54	22	282.54 mm.	3.23368	−6.41436
	VIII : 14 : '54	28	303.22 mm.	3.34795	−6.72936
	IX : 17 : '54	153	174.93 mm.	3.16545	−6.32513
	X : 25 : '54	27	243.89 mm.	3.17786	−6.32349
	XI : 19 : '54	89	252.19 mm.	3.21951	−6.34647
	XII : 19 : '54	224	218.97 mm.	3.13600	−6.18925
	I : 17 : '55	65	228.97 mm.	3.16229	−6.23447
Kumozu	IV : 17 : '54	60	259.24 mm.	3.35076	−6.71730
	II : 18 : '55	20	216.00 mm.	3.11749	−6.19313
	III : 15 : '55	66	250.74 mm.	3.09862	−6.14969

The materials were collected near the sea-coasts of Toyohama, Aichi Prefecture and, Aritaki and Kumozu, Mie Prefecture, during on April of 1954 and March, 1955. Now in order to practise the collection at random, all individuals captured in each experimental fishing were preserved in 10 per cent aqueous solution of formalin for study. (Table 1)

The authors express their sincere thanks to Dr. Chihiro MIYAZAKI, Assistant Professor of this faculty, who has given his support in the collection of the materials.

Results obtained

I. Composition of total length: The seasonal changes of the composition of total length in the three localities are observed as follows (Fig. 2):

A. Aritaki:—Judging from the seasonal change of the composition of total length during the period extending from May, 1954 to January, 1955, it is clear that the two changing processes of the composition are recognizable, that is, the one process is exhibited by a group of smaller individuals which appeared firstly in the material taken in September (total length ranging 125–335 mm., mode: 175 mm.), and gradually increasing length during this season, while the other process exhibited the group of larger individuals occurring continuously from May to August, shows a gradual growth. On and after September, the group of larger individuals was caught together with the group of smaller individuals, but its proportion to the latter was gradually decreased with the advance of the season.

B. Toyohama:—Although the appearance of the group of smaller individuals is less obvious, the seasonal change of the composition of total length has an inclination roughly similar to the case of Aritaki. In October, the group of smaller individuals, having bimode in 205 mm. and 225 mm., was indistinctly recognizable, and moreover, in November, the group having mode in 215 mm. was recognized. But it is doubtful whether these groups are homogeneous in the age with the group of smaller individuals which appeared firstly in the material in September. Probably these groups seem to be consisting of the individuals corresponding to the smaller individuals in Aritaki, and the slow-growing individuals which are referable to the group of larger individuals.

C. Kumozu:—The seasonal change is not traced as the number of collection of material is insufficient.

The results above-mentioned led to the following estimation: The year-classes of these groups differ from each other. The group of younger and newly metamorphosed fish, captured in April to May in Ise Bay in mixing with the Shirasu-group, migrate into the deeper area of this bay, after the growth they will captured by the Sokobiki-ami (a kind of small beam-trawl) in autumn to

winter of this year. This group obviously corresponds to the group of smaller individuals above-mentioned. The group of larger individuals may be consisting of one aged fishes, most of which had metamorphosed in spring of last year. Now, there arise a question why the group of larger individuals are not captured

Fig. 1. Chart of Ise Bay, showing localities mentioned in the text

on and after December. As the gonad was unrecognized macroscopically without exception in all fishes under examination, it may be estimated that the gonad of this fish is probably developed when this fish migrates to the open sea and acquires the suitable environment for the development of the gonad.

II. Relationship between total length and the body weight:

Generally, relationship between total length (body length) and body weight in fishes is expressed in a equation $W=BL^{\alpha}$, and used in the ecological and morphological studies of fishes. Especially the growth coefficient α, which means

the ratio of the logarithmic growth rates for length and weight, the increment in log weight for any period of time of reasonable length being α times the increment in log length for the same period of time, may give the criterion for the differences of populations. In this study, the growth coefficients were calculated on the distinction of each date of collection (Table 1). Moreover, the

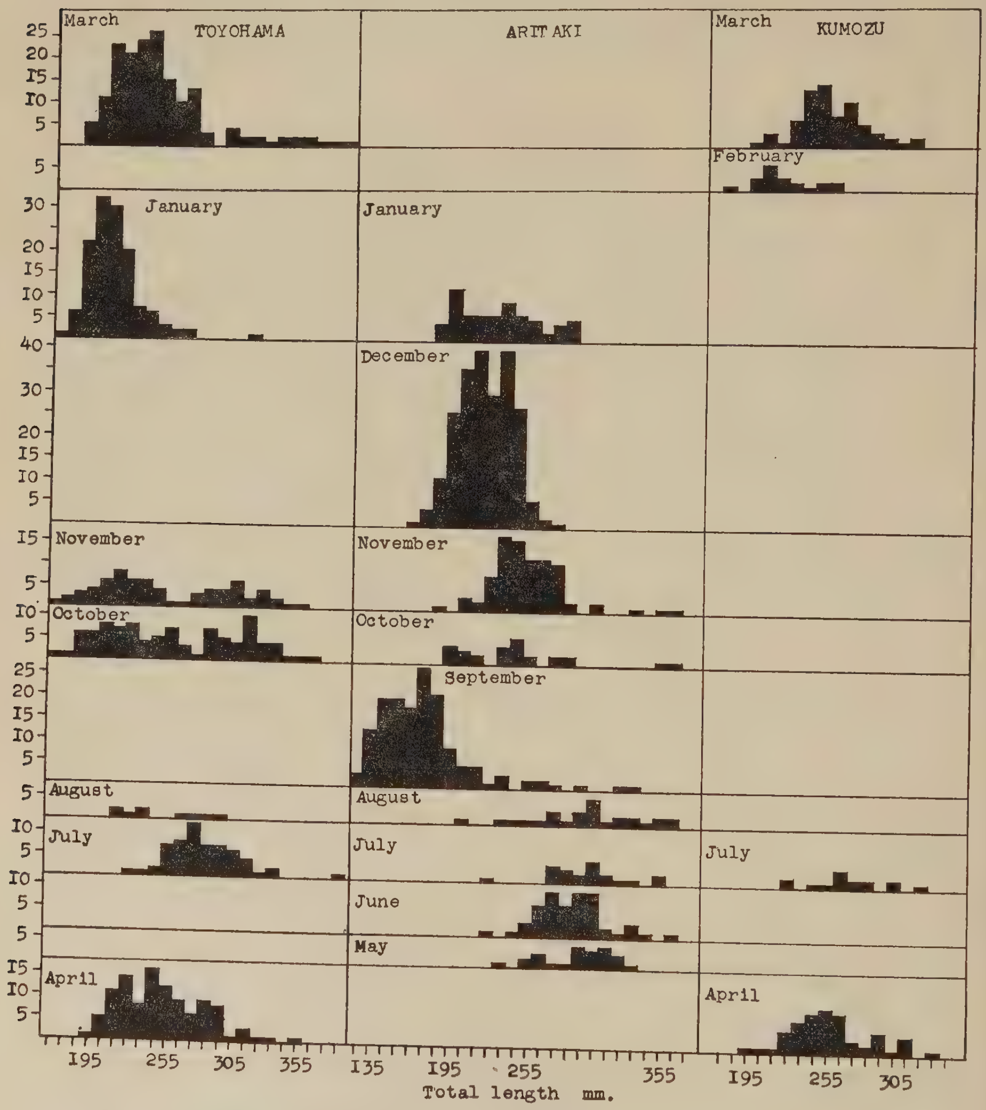

Fig. 2. Seasonal changes of total length composition classified by the locality

seasonal and regional variations of this coefficient were investigated in the light of a stochastic theory. Whether the differences are significant or not, was tested by using ITO's method "Test of significancy of slope differences of allometry lines" (Ito, 1951).

A. Seasonal variation: The seasonal variation of the coefficient in the three localities are traced as follows:

I. Aritaki:—The coefficients varied from 3.13600 to 3.74492 during the period extending from May to January, and the differences between them are significant. (Table 3, A) But, by excepting the material of July of which the coefficient was extraordinarily large, the significant differences between the others are not expected (Table 3, D). Therefore, the remarkable variation is not seemed to exist in this locality.

Table 2. Showing the mean value of relative condition factor

	Toyohama	Aritaki	Kumozu
IV : '54	100.52 102.16 – 98.88		100.55 99.49 – 101.61
V : '54		102.96 103.16 – 102.76	
VI : '54		102.11 102.68 – 101.54	
VII : '54	96.60 96.84 – 96.36	101.68 103.39 – 99.97	
VIII : '54	95.40 97.53 – 93.27	99.12 100.50 – 97.74	
IX : '54		97.18 98.04 – 96.32	
X : '54	93.38 94.27 – 92.49	98.84 100.44 – 97.24	
XI : '54	94.47 95.51 – 93.43	104.52 105.04 – 104.00	
XII : '54		102.45 102.91 – 101.99	
I : '55	103.05 103.56 – 102.54	103.56 105.03 – 102.09	
II : '55			97.96 99.46 – 96.46
III : '55	100.74 102.54 – 98.96		97.37 98.08 – 96.66

II. Toyohama:—The coefficients varied from 3.44543 to 3.63389 in the four materials for March, April, July and August, and from 3.11232 to 3.31851 in the three materials for October, November and January. Namely, the coefficients of the former materials seem to be larger than the cases of the latter materials. As indicated in Table 3, B, the differences between all materials are obviously significant, but when dividing all materials into the four materials and the three materials as above-mentioned, the insignificant differences seem to be recognized in each case. (Table 3, E, F)

III. Kumozu:—The coefficients varied from 2.94718 to 3.35076 in this locality, and the differences between them are insignificant. (Table 3, F) But the number of materials is not sufficient to investigate the seasonal variations.

Table 3. Test of Significancy of "Differences of Growth Coefficient" of each seasonal material

A. Aritaki			
Residue Form	Sum of Squares	(d.f.)	(S.S./d.f.)
Separate lines	0.89172	673	0.00132
Slope differences	0.02873	8	0.00359
Parallel lines	0.92045	681	F_0=2.720**
B. Toyohama			
Separate lines	1.08217	616	0.00146
Slope differences	0.04776	6	0.00796
Parallel lines	1.12993	622	F_0=5.452**
C. Kumozu			
Separate lines	0.25490	140	0.00182
Slope differences	0.00298	2	0.00149
Parallel lines	0.25788	142	F_0=0.819
D. Aritaki (excepting the material for July.)			
Separate lines	0.82165	618	0.00133
Slope differences	0.00444	7	0.00063
Parallel lines	0.82609	625	F_0=0.474
E. Toyohama (4 materials for March, April, July and August)			
Separate lines	0.49153	334	0.00147
Slope differences	0.00927	3	0.00309
Parallel lines	0.50080	337	F_0=2.102
F. Toyohama (3 materials for October, November and January)			
Separate lines	0.59064	282	0.00209
Slope differences	0.01282	2	0.00641
Parallel lines	0.60346	284	F_0=3.067*

B. Regional variation: In order to examine the regional variation of the growth coefficient, the following cases were selected, that is the differences between Toyohama and Kumozu in April, Toyohama and Aritaki in July, August, October, November and January, and Toyohama and Kumozu in March. As the results of test of significancy, the remarkable variations are not occurred between these localities. (Table 4).

Summarizing the above-mentioned facts, the remarkable variation was obviously recognized in Toyohama's seasonal materials alone. In general the variation of the growth coefficient are probably produced by the difference in the growth stages of materials and by that in the other factors, mainly, we believe, environmental. But the growth coefficient of each seasonal materials in Toyohama is seemed to be plotted linearly against their mean value of total length, i.e. these variables do not change independently. (Fig. 3) Therefore, it may be

Table 4. Test of Significancy of "Differences of Growth Coefficient" between two materials collected at the different locality

Residue Form	Sum of Squares	(d.f.)	(S.S./d.f.)
A. Toyohama-Kumozu (April)			
Separate lines	0.32179	160	0.00201
Slope differences	0.00082	1	0.00082
Parallel lines	0.32261	161	$F_0=0.408$
B. Toyohama-Aritaki (July)			
Separate lines	0.11931	78	0.00153
Slope differences	0.00916	1	0.00916
Parallel lines	0.12847	79	$F_0=5.99$*
C. Toyohama-Aritaki (August)			
Separate lines	0.08852	33	0.00268
Slope differences	0.00070	1	0.00070
Parallel lines	0.08922	34	$F_0=0.261$
D. Toyohama-Aritaki (October)			
Separate lines	0.32564	117	0.00278
Slope differences	0.00047	1	0.00047
Parallel lines	0.32611	118	$F_0=0.169$
E. Toyohama-Aritaki (November)			
Separate lines	0.29420	155	0.00190
Slope differences	0.00134	1	0.00134
Parallel lines	0.29554	156	$F_0=0.705$
F. Toyohama-Aritaki (January)			
Separate lines	0.16427	185	0.00089
Slope differences	0.00101	1	0.00101
Parallel lines	0.16528	186	$F_0=1.135$
G. Toyohama-Kumozu (March)			
Separate lines	0.31869	231	0.00138
Slope differences	0.00564	1	0.00564
Parallel lines	0.32433	232	$F_0=4.087$*

concluded that the seasonal variation of the growth coefficient in Toyohama may chiefly be attributable to the growth stage of each material.

III. Condition factor: In this study, in order to explain the variation of the fattness of body, the relative condition factor $K_\alpha = W/BL^\alpha$ (B, α: constant, L: total length, W: body weight) was used. This factor is measuring the deviation of an individual weight from the average weight for length, which was originally used by LeCren, E. D. in his studies of perch (*Perca fluviatilis* LINNÉ). In practise the relationship between total length and body weight of all individuals under examination was first

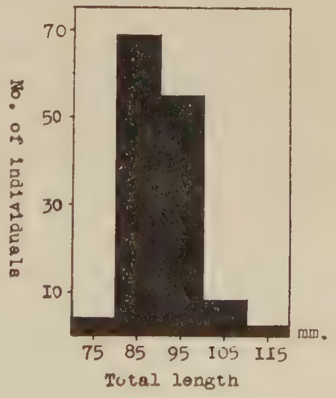

Fig. 3. Total length composition of the young collected near the sea-coast of Shiroko-machi, Mie Prefecture.

calculated as the logarithmic formula, $\log W = -6.52450 + 3.26845 \log L$, and average weights, W, for each length computed from this log formula. Then, the relative condition factors were calculated from the formula, $K_a = W/\hat{W} \times 100$. In order to trace the seasonal and regional variations of the factor, the mean value and its 95% confidence limit of each material were calculated. (Table 2)

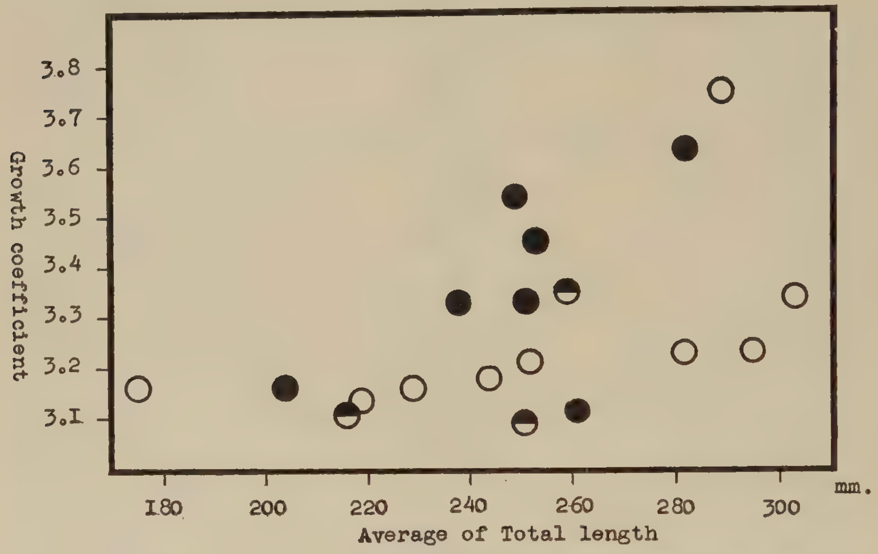

Fig. 4. Relation between the growth coefficient and the average of total length.
Localities:
● Toyohama
○ Aritaki
◓ Kumozu

A. Seasonal variation: The seasonal variations of the mean value of relative condition factor in these three localities are traced as follows:

I. Aritaki:—As indicated in Table 2, the mean values varied from 104.52 to 97.18 during the period extending from May to January, and the cases of August, September and October were seemed to be lower than the cases of the other materials. But, taking 95% confidence limits for the mean values into consideration, the remarkable variation is not expected from the present data.

II. Toyohama:—A rather considerable variation is seemed to recognize in this locality, that is, the mean values for the cases of July, August, October and November are significantly lower than the cases of the other three materials.

III. Kumozu:—A seasonal variation in this locality is not able to trace, owing to the insufficient number of the collection of materials.

B. Regional variation: The significant differences are recognized between Toyohama's and Aritaki's materials for July, August, October and November, and between Toyohama's and Kumozu's materials for April. In the former, the mean

values of Aritaki were always higher than the cases of Toyohama, and in the latter, the mean value of Toyohama is lower than the case of Kumozu.

The causes for these seasonal and regional variations can not be sufficiently explained from the present data. But the following estimation may probably be applicable to the case of the regional variation between Toyohama and Aritaki. Namely, the main cause of this variation may chiefly be attributable to the specialities of the environmental factors, resulted from the course of the inflow of the warm current (Kuroshio) into Ise Bay which is illustrated as follows: The warm current reached at the mouth of the bay flows northwards along the western side of Chita Peninsula and turns to the left its flow direction under the pressure of the streams of fresh water from the Kiso, Suzuka and Kumozu Rivers etc. and finally flows southwards along the eastern side of Mie Prefecture, in leaving for the mouth of the bay. So, the waters at Toyohama are of the rather pure warm current which does just enter into the bay from the open sea, but these at Aritaki are of that mixed with the fresh waters, thereby the differences of these two waters in the temperature, the salinity and the quality and quantity of the food may probably produce the regional difference in fattness of fish populations.

Summary

The present paper is an account of some of the ecological studies of the Ma-anago which was conducted in connection with the investigation of the small trawl fisheries in Ise Bay during the period extending from April, 1954 to March, 1955. The items investigated and the results obtained are summarized as follows:

1. Three localities, Toyohama, Aritaki and Kumozu were selected for the present studies.

2. The composition of total length: By analysing the seasonal changes of the compositions of total length in these three localities, it is clear that the Ma-anago population is at least referable to the two groups, that is, one group is composed with smaller individuals newly metamorphosed in Spring, the other group mostly composing with larger individuals aged one year old after metamorphosis.

3. Relationship between total length and body weight: By using the stochastic method, the seasonal and regional variations of growth coefficient in each material were examined. There is a considerable seasonal variation which is probably effected by the growth stages of Toyohama's materials.

4. Condition factor: By comparing the mean value of condition factor ($K_\alpha = W/BL^\alpha$) of each material, the remarkable seasonal and regional variations were recognized. The former was traced in Toyohama's materials, that is, the mean values of four materials for July, August, October and November were

significantly lower than the cases of the other three materials. The latter was observed between Toyohama's and Aritaki's materials for July, August, October, November and January. In each case, the mean value of Aritaki's is always higher than the case of Toyohama's.

Literatures

Dai 4 Kanku Suiro-bu, 1953: Shōwa 27 nen Saki ni okeru Atsumi-wan oyobi Ise-wan no Kaisho narabini Chōryu Kansoku Hōkoku, pp. 1–4, charts 1–18.

ITO, T., 1951: Stochastical considerations of relative growth, pp. 1–45, Kagaku Kyoiku Kenkyu Kai.

LECREN, E. D., 1951: The length weight relationship and seasonal cycle in gonad weight and condition in the Perch (Perca fluviatilis Linne), Jour. Ani. Ecol., vol. 20, no. 2, pp. 201–219, figs. 1–8.

MIYAZAKI, C., 1955: Investigations of the small trawl fisheries in Ise Bay, Japan, pp. 1–34.

Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 2, No. 2, September 30, 1956.

On the Shell Structures of Japanese Pearl Oyster, Pinctada Martensii (Dunker).*

(I) Prismatic Layer I.

(*With 7 Text-Figures and 2 Plates*)

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Constituents of shells and pearls of marine and fresh-water mussels are 80–99% inorganic compounds, chiefly calcium carbonate, and 0.3–20% organic materials. The organic materials are likely to be divided into several different substances, but at the present time, they are called under the general term of "Conchiolin".

There are three crystal modifications in calcium carbonate; vaterite, calcite and aragonite. HASS (1931) described that marine shells had calcite, and Unionidae had aragonite, in prismatic layer, while all of them had aragonite in nacreous layer. But STOLKOWSKI (1950) examined various kinds of shells by X-ray powder analysis and reported that both layers of *Gryphea angulata* Lmk., *Chlamys varius* L., and *Anomya ephippium* L., were composed of calcite. Besides calcite and aragonite, vaterite was detected in Gastropoda by MAYER (1931), MAYER and WEINECK (1932), and STOLKOWSKI (1950).

Meanwhile, Japanese pearl oysters, *Pinctada martensii* (DUNKER) are known to have calcite and aragonite as a main constituent of the prismatic and nacreous layer, respectively. Besides, crystals of tri-calcium phosphate are found in both layers (WATABE (1956), WADA (1956)).

As for structures of shells or pearls, many reports have been published, and recently TSUJII, SHARP and WILBUR (1955) studied submicroscopic structure of *Crassostrea virginica* GMELIN with an electron microscope. But, very few have been done concerning the shells of *Pinctada martensii*.

The present report deals with the structures of prismatic layers of the pearl oysters observed with electron and optical microscopes.

The authors express their sincere thanks to Dr. Yaichiro OKADA, Dean of the Faculty of Fisheries, Prefectural University of Mie. Dr. Keiichi OMORI, Professor of Tohoku University, and Mr. Katsuo TAKAYAMA, Director of National

* Contributions from National Pearl Research Laboratory, No. 7.

Pearl Research Laboratory for their kind encouragements. Their thanks are also due to Mr. Nozomu MORITO and others in Hitachi Central Laboratory for their helps in preparation of specimens for electron microscopy.

Materials and Method

Materials used for the observations were shells of 3 aged *Pinctada martensii* (DUNKER), cultured at the depth of 1.5 meters in the sea near Tatoku Island, Mie Prefecture, and collected in September–November, 1955.

For electron microscopy, methyl-methacryl aluminium replicas shadowed with chromium were prepared from the inner surface of the prismatic layer cleaned with water and alcohol.

Replicas were also obtained from the sections cut vertically to shell surface and etched slightly with 0.25–0.1% HCl for 25 seconds.

Horizontal and vertical thin sections were observed under a polarized microscope.

Observations

Under an optical microscope, the prismatic layer is observed to be composed of many prismatic chambers, 5–100 μ in diameter, closely compacted together and show a bee-hive structure.

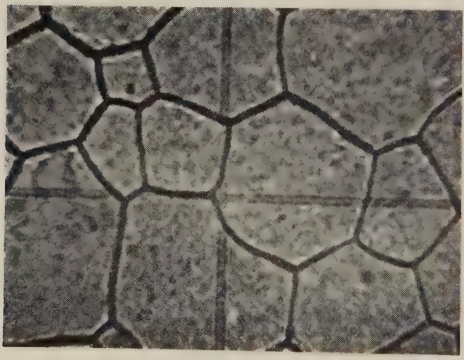

Fig. 1. Polygonal chamber of the prismatic layer. (Horizontal section) Open nicol. ×310.

Fig. 2. The same layer in Fig. 1. Crossed nicols.

The horizontal surface indicates net-works of polygons (Fig. 1) and the vertical section aggregates of rectangles (Fig. 3). Calcite crystals are packed inside the chambers, walls of which are made of conchiolin forming polygonal outlines. The chambers are also interpenetrated horizontally by many conchiolin fibres.

Under crossed nicols, whole area of each chamber in the horizontal section does not extinct at the same time, but shows flamboyant, or partial irregular

Fig. 3. Vertical section of the prismatic layer. Open nicol. ×310.

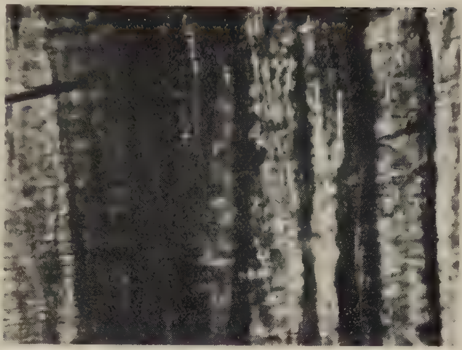

Fig. 4. The same layer in Fig. 3. Crossed nicols.

extinction (Fig. 2); it can be divided into several extinction blocks, 2–15 or 5–30 μ in diameter.

In the vertical section, too, the chamber is observed to be divided into canie-shaped sub-chambers, 5–30 μ in width, constituted of micro-chambers, 2–15 μ. The micro-chambers show oblique extinction to the vertical walls of conchiolin with different extinction positions.

Those characteristics mean that several crystals are contained in every chamber so as to have their a- and b-axes oriented in different directions from one another, and c-axes perpendicular (or inclined slightly) to the surface.

Near the boundary between the prismatic and nacreous layers on the inner surface of the shell, the chambers become smaller and take rounded forms, with the conchiolin walls getting wider (Fig. 7). Smaller crystal blocks, 1–6 μ, are located radially along the walls (Fig. 5). Every block shows partial extinction (Fig. 6).

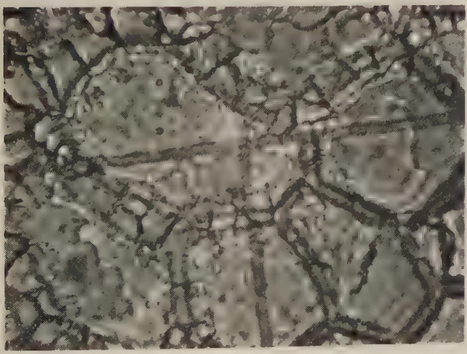

Fig. 5. Smaller crystals along the conchiolin walls of the polygons near the nacre. (Horizontal section) Open nicol. ×310.

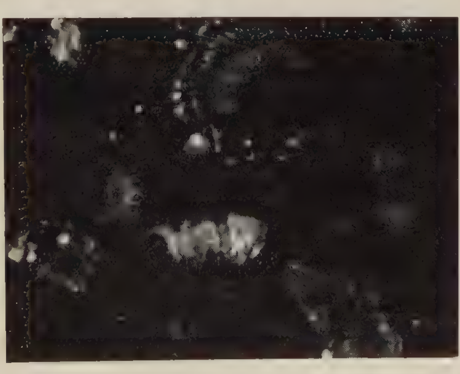

Fig. 6. The same crystals in Fig. 5. Crossed nicols.

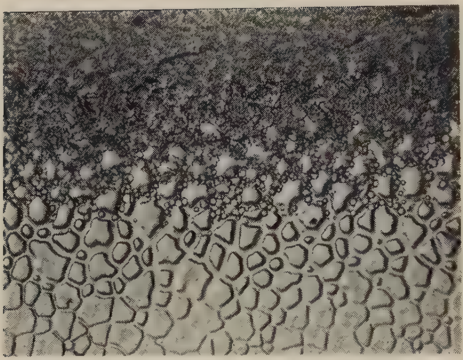

Fig. 7. Inner surface of the prismatic layer near the nacre. ×80.

These findings have no significant difference from those in *Pinna*, *Mytilus*, *Anodonta*, etc. by earlier workers.

When the surface is observed with an electron microscope, polygonal conchiolin walls which are pressed by crystals are, as in *Crassostrea virginica* by TSUJII et al (1955), found running as grooves between the crystals. The grooves are about 0.5–1.0 μ in width at the middle part and outer margins of the layer (Pl. XVIII, Fig. 1). Approaching to the nacreous layer, their width increase up to 6–17 μ and their depth decrease (Pl. XVIII, Fig. 2).

Electron micrographs of vertically cut and slightly etched surface reveal that thick conchiolin walls (1.5–2.0 μ) are standing normally to the shell surface (Pl. XVIII, Fig. 3 and XIX, Fig. 4). The walls correspond to the polygonal ones on the surface. Very thick wall, seen at the left part of Fig. 3, seems to be a vertical section of a part where three walls meet together. A horizontal wall is situated at the lower part. Between those walls, thinner ones run in parallel with distances of 4–12 μ from one another (Pl. XIX, Fig. 5). One or two calcite crystals, 2–5 μ in size and length, occupy each chamber which is limited by the walls. Those crystals are considered as the smallest elements which build up the prisms.

Synthesizing the above mentioned observations, the prismatic layer can be explained as the aggregates of polygonal prismatic chambers composed of sub-chambers which are divided into micro-chambers containing several single crystals of calcite. Conchiolin is pressed by the crystals to form walls of all the chambers, with specially large thickness around the polygons. When Fig. 1 is carefully examined, the micro- or sub-chambers can be noticed, too.

Under high magnification, very fine crystals could be seen to be scattered on a surface of polygonal chambers (Pl. XIX, Fig. 6). All of those fine crystals are likely to be deposited on conchiolin membrane. They had hexagonal tabular form, elongated slightly. The size varied between 0.3 and 2 μ. They were isolated, or twinned, and some of them combined together. In some part of the surface, the aggregates built comparatively large sheets and the margins formed steps.

Horizontal surfaces of the crystals are basal planes (0001). Angles between the edges showed 120° and, in rare occasion, 150° and 90°. Therefore, dominant planes in the crystals are considered as basal planes (0001) and unit prisms (1010). Some crystals had diagonal prisms (1120) besides the two planes. On

the corner of basal planes, finer crystals were in the process of development with over-growth.

When the small size and the mode of aggregation of the crystals are taken into considerations, the configurations seem to indicate an earlier stage of crystal growth of calcite. Solutions of calcium carbonate being supplied more and more, the crystals will grow up to a few blocks of larger crystals, 2–5 μ mentioned before, and the basal conchiolin membrane will become a horizontal wall.

On the membrane near the boundary between prismatic and nacreous layers, much smaller crystals were deposited. They had no definite forms. They are considered to be in the first stage of crystal growth.

Summary

Prismatic layers of *Pinctada martensii* were observed with electron and optical microscopes.

1. The layer is built up with polygonal prismatic chambers, 5–100 μ, composed of sub-chambers, 5–30 μ, which are divided into micro-chambers, 2–15 μ, containing several calcite crystals (2–5 μ).

2. Conchiolin is pressed by the crystals to form walls of the chambers. On the inner surface of the shell, the polygonal walls run as grooves between the crystal portions with the width of 0.5–1.0 μ. Near the nacreous layer, they come to be wider.

3. C-axes of the crystals are oriented nearly perpendicular to the shell surface, and a- and b-axes oriented randomly.

4. On the inner surface of the shell, very fine tabular crystals (0.3–2 μ) with basal planes, unit prisms and diagonal prisms could be observed. They are considered to be at an earlier stage of crystal growth.

References

HASS, F., 1931. Klass. u. Ord. d. Tier-reichs; Bd. III. Abt. III, Biv., 194–233.

MAYER, F. K., 1931. Jenäische Zeitschr. Naturwiss., **65**, 487–512.

——————, ——. Chem. d. Erd., **6**, 239–252.

MAYER, F. K. and WEINECK, E., 1932. Jenäische Zeitschr. Naturwiss., **66**, 199–222.

STOLKOWSKI, J., 1950. Théses présentée a la fac. sci. l'univ. Paris, Série A, **2352**, 14–30.

TSUJII, T., SHARP, D. G. and WILBUR, K. M., 1955. Anat. Rec., **122**, 3, 432.

WADA, K., 1956. Under printing.

WATABE, N., 1956. SHIZEN, XXVI, **7**, 359–360.

Explanation of the Plates XVIII–XIX

Electron micrographs of the prismatic layer of *Pinctata martensii.*

Fig. 1. Inner surface of the layer. Outlines of the polygonal chambers are made of conchiolin walls running as grooves between the crystal portions. The chambers are divided into sub- and micro-chambers.

Fig. 2. Inner surface of the layer near the nacre. Conchiolin walls are wider than those in Fig. 1.

Figs. 3, 4 and 5. Surfaces of the layer cut vertically to the shell surface, showing thick conchiolin walls and thinner ones standing perpendicular to the surface. Horizontal walls are also observable.

Fig. 6. Micro-crystals of calcite on the inner surface of the layer.

1
2
5μ
3

4

5

6

Report of Faculty of Fisheries,
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Vol. 2, No. 2, September 30, 1956.

Copepods Parasitic on Japanese Fishes

10. The Redescription of Three Species of *Caligus*

(*With 4 Text-figures*)

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In a series of my previous papers published in Annot. Zool. Japon., Vol. 27, 1954, I reported 3 new species of the genus *Caligus: C. triangularis, C. fulvipurpureus*, and *C. glandifer*. In describing them I confined myself to the points indispensable for their definition, as limits of space prevented my going into detail. Here, I propose to give additional accounts, especially on the appendages and to make, if necessary, a few remarks on the specimens other than the types. But repetition of what I have stated before will be minimized*.

Caligus triangularis SHIINO

(Figs. 1 & 2)

SHIINO 1954, Annot. Zool. Japon., Vol. 27, pp. 146–149, Fig. 1.

Host: *Halichoeres poecilopterus* (T. & S.).

Locality: Hamazima, Mie Prefecture.

Female: Distal joint of 1st antennae relatively short and broad, thickly setose at tip; proximal joint fringed with stout plumose spines along anterior margin. Of two spines on apical joint of 2nd antennae, proximal one is replaced by broad falcate lobe, though distal one is of usual nature; posterior process on basal joint blunt, finger-like. First maxillae hook-like, with tip of hook sharp and making an obtuse angle with broad base. Second maxillae triangular, slightly curved outwards, and bluntly pointed. Distal joint of 1st maxillipeds slender, furnished somewhat beyond centre of joint with a semicircular, finely pectinate membrane; terminal claws unequal, with twisted rows of fine hairs along their lengths. Finger of 2nd maxillipeds with a short spinule a little behind apex. Arrangement of spines and setae on 4 pairs of natatories is as shown in the diagram inserted at the top of next page**:

* This is a part of the results enabled by the financial aid from the Scientific Fund of the Ministry of Education.

** Abbreviations in the tables: c, row of hairs; cc, hairy area; f, membraneous flange; H, longer spine; h, shorter spine; H′, hook; P, longer plumose spine; p, shorter plumose spine; Q, spine with row of hairs on one side, membrane on the other; rh, rudimentary spine; s, solitary hair. Roman numerals indicate the numerical orders of legs or of joints and Arabian ones the number of armaments present on each of them.

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer		1p		1h	3h, 1p				
	inner		1p		c	3Q				
II	outer	f		f, 1s	f, 1H	1H	1rh, 1H, 1Q	c	cc	cc
	inner		1P	f, 1s	c, 1P	c, 1P	5P	1P	c, 2P	6P
III	outer	f	f, 1p		c, 1H	c, 3H			c	
	inner		1P, f, 2s, c		c, 1P	4P		1P	6P	
IV	outer		1p		1H	3H				
	inner									

Inner spines on 3rd joint of 1st legs have inner border fringed with a row of hairs, and outer border marginated by a narrow membrane leaving a few short downy hairs at base; the membrane ornamented with short oblique parallel striations on its surface extending entire length. Of 3 outer spines on 3rd exopod joint of 2nd legs, basal one reduced into a tiny seta, middle one stouter, with outer narrower, crescentic and inner broader, semilunar rims, and terminal one with inner row of hairs and outer finely pectinate membrane; external spines on basal 2 joints of same ramus simple. Two rami of 3rd legs apart from each other; exopod 2-jointed, while endopod substantially 1-jointed, having basal joint almost reduced. Hook at base of exopod has blunt apex and striped rim at outer distal angle of basal portion. Two distal joints of 4th legs subequal in length; innermost of apical spines much longer than others, which are subequal and slightly shorter than the one on 2nd joint. Caudal rami carry 2 short plumose spines at outer distal angle and similar 1 at inner angle, besides bearing far longer terminal spines; inner border of the rami hairy. (An example of female with pentagonal genital segment alluded in my previous report is illustrated in Fig. 2, A.)

Male: First and 2nd joints of 2nd antennae sporadically covered with parallel ridges which give their surface a file-like appearance. These are conspicuous on subterminal bulge of 2nd joint and on small basal area of anterior side, but less so on ventral surface and on posterior side of 1st joint. Second maxillae relatively shorter than in female, with their broad crescentic base abruptly narrowing to continue rod-shaped terminal portion which ends in blunt apex and is traversed with fine parallel striations close to base. Finger of 2nd maxillipeds with 2 spinules arranged proximo-distally on inner border. On each side of midline and just inside the base of those limbs there is a narrow longitudinal ridge crossed by fine stripes.

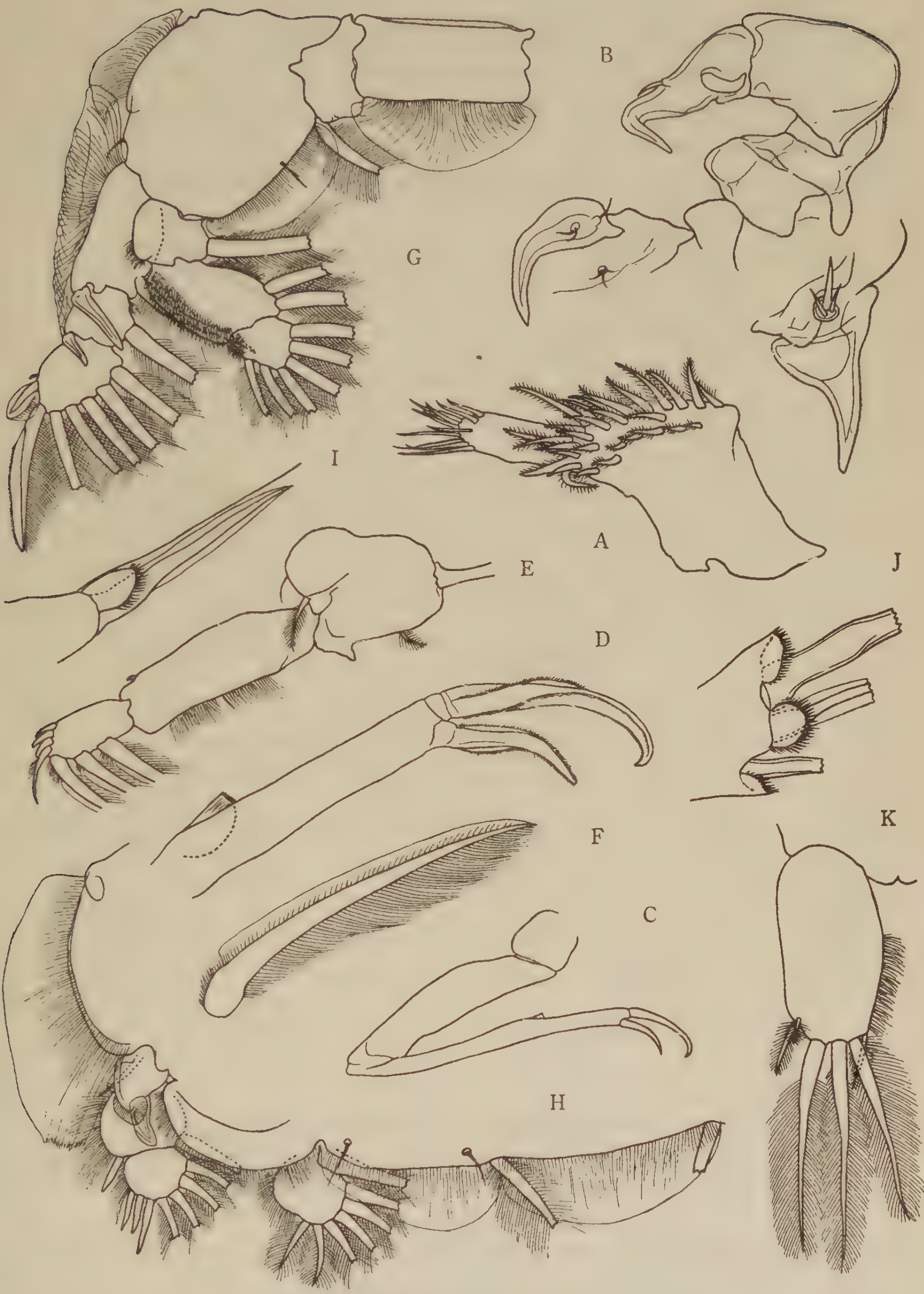

Fig. 1. *Caligus triangularis* SHIINO, female.

A, 1st antenna; B, 2nd antenna, 1st and 2nd maxillae in situ; C, 1st maxilliped; D, apical part of same; E, 1st leg; F, a spine on inner border of terminal joint of same; G, 2nd leg; H, 3rd leg; I, spine on penultimate joint of 4th leg; J, spines on terminal joint of same; K, caudal ramus. A, B ×170, C, E, G, H, K ×120, D, F ×340, I, J ×490.

Young female: 2.43 mm × 1.49 mm (exclusive of caudal rami). Carapace somewhat more strongly narrowed forward than in adult; median lobe widely round on margin and making angle at each lateral corner. Fourth thoracic segment short, transversely linear, 1/4 as wide as carapace, with angular sides and arcuate posterior border. Genital segment about 2/7 as long and 2/5 as wide as carapace, with configuration approximating a sector; sides convergent forward

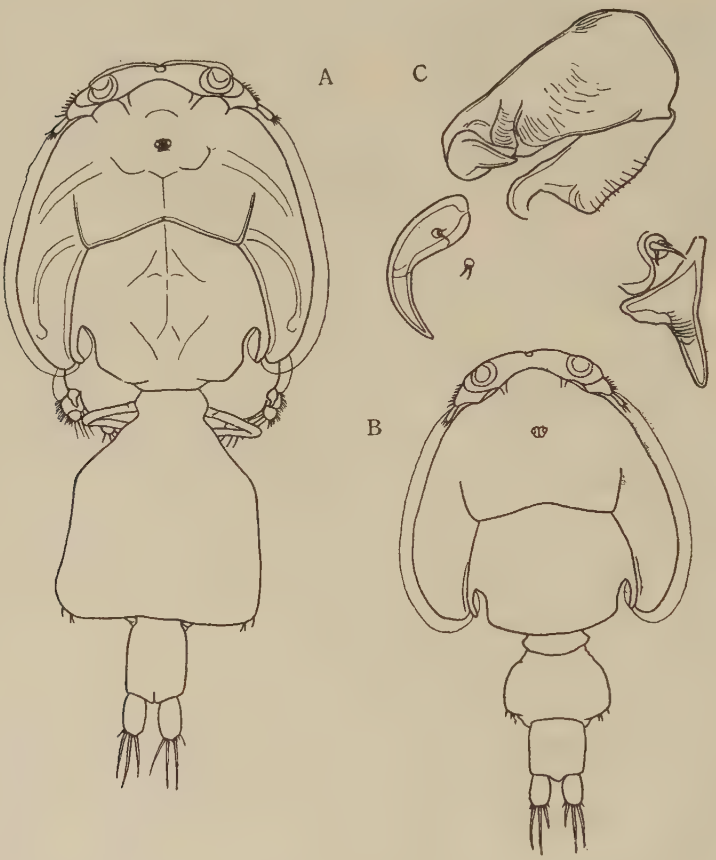

Fig. 2. *Caligus triangularis* Shiino.
A, female with pentagonal genital segment; B, young female; C, 2nd antenna, 1st and 2nd maxillae of male in situ. A ×27, B ×24, C ×170.

describing a graceful curve, but insensively wrinkled near anterior end. Arrangement and number of spinules on that segment same as in adult. Abdomen relatively large, quadrilateral, about 2/7 as long as carapace, and as wide as its own length. In other points as in adult.

Caligus fulvipurpureus SHIINO

(Fig. 3)

SHIINO 1954, Annot. Zool. Japon., Vol. 27, pp. 150–153, Fig. 1.

Host: *Cololabis saira* (BREVOORT).

Locality: Owase, Mie Prefecture.

Female: First pair of antennae as usual in structure, with joints thickly spinulose. Claw of 2nd pair well-bent, with 2 very short spinules; Posterior process on basal joint conical. Second maxillae short, nearly triangular, having broad base and bluntly pointed apex, edged with rudimentary blade. Distal joint of 1st maxillipeds slender, longer than basal joint, and with a narrow crescentic accessory lobe a short distance behind apex; terminal claws unequal in size, with narrow finely pectinate membranes along their lengths. Finger of 2nd maxillipeds not much curved, of uniform breadth throughout its length with the exception of sharply pointed, curved ungulus, and bearing 2 short spines, one on inner border close to base of ungulus and the other on posterior face a little behind. Arrangement of spines and other armaments on 4 pairs of legs may be clarified by the following table:

Leg	Border	Sternal plate	Protopodite		Exopodite			Endopodite		
			I	II	I	II	III	I	II	III
I	outer		1P		1h	3h, 1H				
	inner		cc		f	3Q				
II	outer	f		f, 1s	f, 1H	1H	1rh, 1H, 1Q		cc	cc
	inner		1s, P	f, 1s	c, 1P	c, 1P	c, 5P	1P	c, 2P	6P
III	outer	f	1f, 1h		1H′, c, 1h	c, 3h			c	
	inner		1P, f, 2s, c		1P	c, 4P		1P	6P	
IV	outer		1p		1P	3P				
	inner									

Plumose spines on apical joint of 1st legs have bordering hairs of one side replaced by a membrane though retained in a short basal part. Hind border of 2nd joint marginated with a membrane instead of hairs. Basal joint has broad oblong area, thickly covered with minute hairs, along posterior margin and carries a triangular rudiment of endopod near outer end. Sternum just behind 1st pair of legs with oval tubercles, disposed one on each side of midline. External spine on each of first 2 exopod joints of 2nd legs with narrow rims. Basal one of external spines on 3rd joint short and feeble, middle one stouter, with crescent, striated, inner membrane, and apical one longer than twice of middle

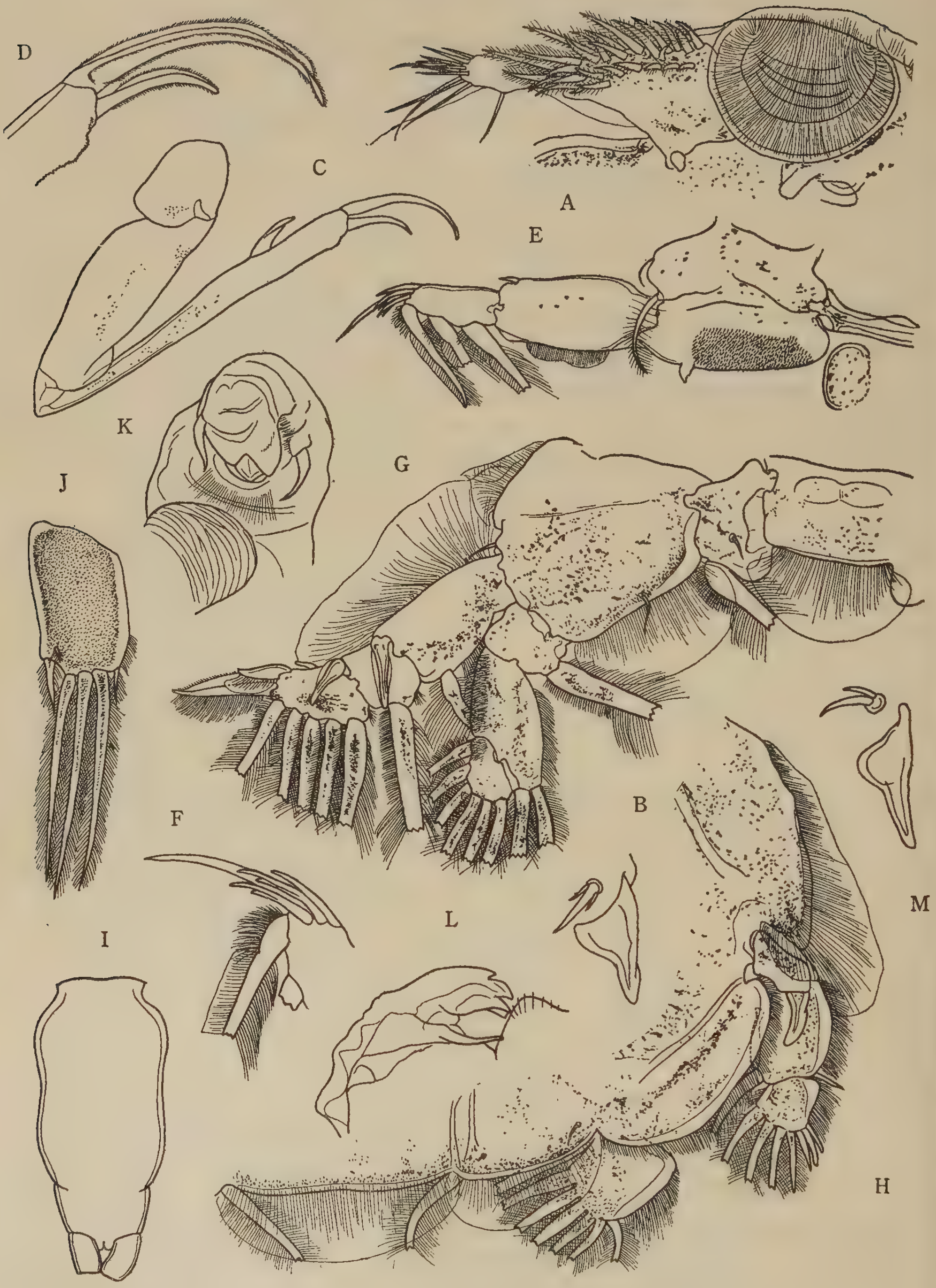

Fig. 3. *Caligus fulvipurpureus* Shiino.

A–I, female; A, 1st antenna; B, 2nd maxilla; C, 1st maxilliped; D, apical part of same; E, 1st leg; F, terminal part of same; G, 2nd leg; H, 3rd leg; I, abdomen, dorsal view; J, caudal ramus; K–M, male; K, tip of 2nd antenna, ventral view; L, same, posterior view; M, 2nd maxilla. A–C, E, G, J ×80, D, F ×170, H ×50, I ×27, K, L ×340, M ×120.

one, with inner row of hairs and outer pectinate rim. Rami of 3rd legs widely apart; exopod 2-jointed, while endopod 1-jointed, with basal joint highly degenerated; basal hook of exopod curved in a sickle-shape, its apical part with rudimentary external rim. Basal joint of 4th legs longer than 2 terminal ones combined. Three apical spines on 4th legs graded in lengths from within outward, the longest attaining twice the shortest; spine on 2nd joint subequal to the middle of apical ones; all of them edged with fine pectination or with pectinate membranes. Caudal rami more or less hairy on inner border, and with a short plumose spine on each side of far longer terminal spines and very tiny additional one on outside.

Male: Claw of 2nd antennae with 3 triangular teeth on its external surface and with 2 basal spinules, disposed one on anterior and posterior sides respectively. Second joint has an oval, subterminal, ventral bulge, covered with fine rasp-like ridges; posterior face succeeding this bulge, basal part of anterior face, and posterior face of basal joint occupied by similary ridged areas. Finger of 2nd maxillipeds nearly straight, of uniform thickness, with acute, slightly curved ungulus, and with a short spinule close to its base; molar-like protuberance of palm showing rasp-like surface.

Caligus glandifer SHIINO

(Fig. 4)

SHIINO 1954, Annot. Zool. Japon., Vol. 27, pp. 154–156, Fig. 1.

Host: *Zenopsis nebulosa* (T. & S.)

Locality: Owase, Mie Prefecture.

Female: Frontal plates emarginate on the median, and carrying a short spinule inside each lunule. Lateral margins of carapace with a similar spinule 2/3 behind anterior end. First antennae thickly spinulose at tip; plumose spines fringing anterior border of basal joint rather long and stiff. Terminal claw of

Leg	Border	Sternal plate	Protopodite I	Protopodite II	Exopodite I	Exopodite II	Exopodite III	Endopodite I	Endopodite II	Endopodite III
I	outer		1p		1h	3H, 1P				
	inner		1p		c	3P				
II	outer	f		f, 1p	f, 1H	1H	1h, 1H, 1Q	c	c	c
	inner		1s, 1P	f, 1s	c, 1P	c, 1P	5P	1P	2P	6P
III	outer	f	f, 1p		1H′, c, 1H	c, 3H			c	
	inner		1P, f, 1s, c		1P	c, 4P		1P	6P	
IV	outer		1p		1H	1H, 3H				
	inner									

2nd antennae sharp, well-curved, with 2 short spinules as usual; basal joint with rhomboid posterior process. First maxillae hook-like, with blunt tip. Second maxillae narrow lobes, of uniform width except for having broader base, blunt

Fig. 4. *Caligus glandifer* SHIINO, female.

A, 1st antenna; B, 2nd antenna, 1st and 2nd maxillae in situ; C, 1st maxilliped; D, apical part of same; E, 1st leg; F, endopod of same; G, 2nd leg; H, 3rd leg; I, terminal part of 4th leg; J, postero-lateral angle of genital segment, abdomen and caudal ramus, ventral view. A ×120, B ×95, C, G, H, J ×85, D ×170, F, I ×340.

at end, and with a minute inner tubercle somewhat behind. Distal joint of 1st maxillipeds slender, carrying a foliaceous subterminal lamella; claws of unequal lengths, rimmed with finely pectinate narrow membranes, which are twisted near apex of longer claw around its axis. Finger of 2nd maxillipeds ends in sharp, slightly curved ungulus which bears a basal spinule. Arrangement of spines and setae on 4 pairs of swimming legs is as indicated in the table inserted on page 239.

Rudiment of endopod on 1st legs mammiform, obscurely 2-jointed, tipped by minute spinules. External spine on first 2 exopod joints of 2nd legs doubly edged with narrow rim; basal member of 3 external spines on apical joint short, feeble, somewhat incurved, middle one stouter but only slightly longer, with inner lunular membrane, and apical one long, hairy on inside, while rimmed with membrane on outside. Two rami of 3rd legs apart; exopod 2-jointed, endopod 1-jointed, having 1st joint largely absorbed by basal apron; hook at base of exopod with a narrow crescentic outer rim on basal portion, and terminal portion relatively long, falciform, ending in blunt tip.

Basal joint of 4th legs as long as rest 2 joints combined, of which penultimate one is rather short; all spines subequal in length except innermost of apical ones which is much longer. Caudal rami armed with 2 short plumose spinules at outer distal angle and a similar one at inner angle in addition to longer terminal ones.

References

1. SHIINO, S. M., 1954. On *Caligus triangularis* n. sp., a copepod parasitic on *Halichoeres poecilopterus* (T. & S.). Annot. Zool. Japon., Vol. 27, pp. 146–149.
2. ———, 1954. A new fish-louse found on the Mackerel-pike. Ibid., Vol. 27, pp. 150–153.
3. ———, 1954. A new fish-louse found on *Zenopsis nebulosa* (T. & S.). Ibid., Vol. 27, pp. 154–156.

Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 2, No. 2, September 30, 1956.

Copepods Parasitic on Japanese Fishes

11. Genus *Phrixocephalus*

(*With 14 Text-figures and 1 Plate*)

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Phrixocephalus is a genus of lernaeid copepods which shows the peculiar mode of life to live upon marine bottom-fishes inserting the anterior part of body in the eye. So far as I am aware, it has been known from 4 species: *cincinnatus* WILSON, *triangulus* WILSON, *diversus* WILSON and *cepolae* YAMAGUTI. Although the first of these has come from the coast of California, the rest is confined to Japanese waters except for the doubtful record of the second from Tierra del Fuego, Argentina. Among my collection of the parasitic crustaceans, there are a number of specimens apparently referable to this genus and these afford 7 new species besides including *cepolae*. Another material which has been sent to me from the Biological Laboratory of His Imperial Majesty for identification comprises one more new species and *triangulus*. The present paper deals with these species. Specimens other than the property of that Laboratory will be preserved in the Prefectural University of Mie.

Grateful acknowledgement is made to Dr. K. HATTORI of the Biological Laboratory of His Imperial Majesty for many courtesies extended to me.

Genus *Phrixocephalus* WILSON, 1908

The animal inserts its head and the anterior portion of thorax up to the 4th segment in the eye ball of the host through a narrow hole, which it usually burrows near the upper margin of the cornea above the crystalline lens. The portion of thorax buried in the eye is always narrowed in the form of a cylinder lacking any segmentation, which is usually called the neck. Although the boundary between the head and the neck is in many cases indistinct, the former appears to be rather short, since the rudiments of the 1st thoracic legs can be made out close to the anterior end of that cylinder. The body abruptly enlarges, when it emerges out of the eye, to form enormously swollen, banana-like segment which bears at caudal end a pair of coiled egg-tubes enclosing a row of flattened eggs. This segment, which is customarily called trunk, corresponds to the genital segment of ordinary copepods and the abdomen is reduced to a mere knob. The neck intrudes into the eye almost perpendicularly, trailing the trunk alongside

of the host head, so that the two portions meet at right angles just at the outer surface of cornea.

The fixation of body within the host eye is insured not only by the neck, but also by the filiform processes which project from the side of the head and send forth many branches and branchlets. Spreading throughout the wall of eye ball on its median side, these, as a whole, make an umbrella-like organ which takes firm hold of the ball to become an effective anchor. They are enveloped by the cyst-like thickening of the chorioid tissue of the eye, but invade neither the sclera, nor the retina. They may, however, occasionally get entangled with the tapetum nigrum, or with the argentea. In rare case, some of them emerge out of the retina to lie exposed in the interior of eye chamber. The central part of head is placed on the ventro-median wall of eye in the close vicinity of optic nerve, or of chorioid gland, the rich supply of blood around these furnishing the parasite with the source of its food. Oral part and its immediate circumference, therefore, are not applied to the host cyst, but lie exposed in the narrow space between the eyeball and the eye-socket. This region is bounded around it by a somewhat more thickened ring of cyst.

Getting out of the wall of the median side, the neck makes its appearance in the interior of eye chamber, but it is still enclosed all around by the thin layer of retina which is unaccompanied with tapetum nigrum. After a short traverse across that chamber, the neck reenters the wall of eye ball at the dorsal corner of iris, where it thrusts out 2 pairs of chitinous horns which are disposed dorsiventrally. These horns, branching within the iris, provide another support for the anchoring of body. In one case, namely in a young individual of *Ph. triangulus*, it has been observed that one of the horns thrusts the tip out of the cornea. In all other specimens, however, the horns are entirely confined within the wall of eye ball, the base of neck alone emerging from the burrow.

Owing to the underlying cephalic processes, the inner surface of eyeball shows irregular ridges which are found not only in the immediate neighborhood of the entrance point of the neck, but also over the whole area of the median side wall. It is problematical, therefore, whether the fish carrying *Phrixocephalus* can ever use its visual sense effectively, though the crystalline and campanulla Helleri are left unaffected. Integument covering the posterior half of neck is especially tough in chitin, this being apparently due to the necessity of resisting the current of water against the exposed trunk as the host moves.

In addition to the bent, there is a twist of the surface of body around its axis. As pointed out by WILSON (1908), the body is "twisted a quarter of the way around, so that when the creature is lying on the side of its genital segment the head and neck present either dorsal or ventral surfaces." In the parasite from the right eye, for example, if the head and neck are laid down with the

dorsal face upward, the trunk shows its left side with the caudal end directing rightward. In the one from the left eye, the relation being reversed, the trunk comes to the left of the neck to show its right side. Thus, this asymmetrical animal affords two kinds of individuals within one and the same species, one sinistral and the other dextral, according to the side of the eye to which it attaches.

As regards the morphology of this genus, especially concerning the appendages, I feel it necessary to make some remarks. Wilson (1917), in his diagnosis of the genus, stated that the 2nd pair of antennae are chelate, in spite of that he never made any mention of these in describing his 3 species. He showed, in his drawing of the head of *triangulus* (1917, Pl. 9, Fig. 82), a pair of small tubercles with 2 minute unguli on the dorsal surface some distance behind the extreme anterior margin, lebeling them as the 2nd antennae. I have carefully examined the head of this species on the material available. Contrary to my expectation, I have failed to find out such appendages, being confined to observe fat globules or the drops of the tissue fluid of host adhering scatteringly over the surface. The globules could easily be removed even by the slightest touch of needle and could not be regarded as anything like the rudiment of appendage. In other species also, the state of things was the same. I presume that Wilson mistook those globules for the 2nd antennae.

Tiny processes showing a bouquet-like arrangement on the central part of the head surface were termed by Wilson (1917, 1922) the frontal processes. Although Wilson did not make the true nature of these processes clear, Yamaguti (1939), in his study of *Ph. cepolae*, considered them as to represent the 2 pairs of antennae. I am in complete agreement with this view. As may be clear from the text-figures inserted in the following pages, the processes are divisible into 2 pairs of groups in many cases, those of each group arising from a common peduncle. They interpose between the members of either side the oral cone, and, considering from their relative position, it appears they represent the 2 pairs of antennae, though they cannot easily be discriminated from each other when the ramification is especially profuse.

Yamaguti discovered a small 3-jointed appendage just inside the base of the 2nd antenna and I have recognized similar one also in *triangulus* and *arboreus* (Figs. 2, C, E & 10, C), It is composed of 2 rod-like basal joints and an unguiform terminal joint, geniculation intervening between the basal joints (Fig. 2, E). The named author appears to take this appendage for the endite of the 2nd antenna. But an endite showing such a structure has not been known in any of the antennae of lernaeids. The appendage, on the other hand, bears a close resemblance in its costitution to the 1st maxilliped (maxilla of Wilson) of other lernaeids, e.g. *Peniculus*, *Peniculisa*, *Lernaenicus*, etc., though much

smaller in size than in these. It does not arise from the antenna as YAMAGUTI described, but from the ventral surface of head just inside the base of antenna. It is occasionally invisible, being concealed beneath the ramified antennae.

The maxilla has been overlooked in any of the species hitherto known. I found this in *triangulus* in the narrow space between the antennae and the oral cone, and a short distance in front of the maxilliped (Fig. 2, D). The maxilla consists of a rather short base and 2 elongate flagella. Oral cone is figured for the first time (Fig. 2, F, G). It is made up of narrow triangular labrum and broad labium. The latter, which occupies far greater part of the circumference of the cone, is wrapped by the former from the front to fill the antero-median sinus. The cone encloses a pair of styliform mandibles, each of which ends in 2 tuberculiform apices.

As regards the thoracic legs, misleading resulted from the incompleteness of dissection is prevailing. WILSON (1907) spoke of *cincinnatus* as having 2 pairs of 3-jointed uniramous legs attached close to the mouth. He mentioned, afterwards (1917) in describing *triangulus*, that it possesses 4 pairs of setaceous swimming legs which are indistinctly jointed. The first 2 of these are biramous and crowded together toward the posterior end of the head, whereas the last 2, being uniramous, are apart from them as well as from each other. He (1922) recognized the similar legs in *diversus*, adding at the same time that the ramus of the last legs is definitely 1-jointed. On the other hand, YAMAGUTI stated, in the description of his species *cepolae*, that while the first 2 pairs of legs are uniramous, having 2-jointed ramus, the 3rd is devoid of any ramus and the 4th is absent. These tiny legs, being appressed to the cyst wall of the chorioid of host eye, are liable to become detached from the neck segments, when one tries to take out the parasite from the cyst, and it is not unusual that the rami or one of them are disjoined from the protopodite. Moreover, they are covered on their surface by the fine granules of deposit derived from the host tissue fluid, which make the observation rather difficult and are apt to lead one to an erroneous conclusion. So far as my observation goes, the first 2 pairs of legs are biramous and the last 2 uniramous, each of the rami being definitely 2-jointed (Figs. 2, 7 & 10). The terminal joint is fringed with plumose spines in all the legs and the protopodite bears a short simple hair on the outside. The last pair of legs which are ordinarily present just inside the bases of the ventral thoracic horns are sometimes absent. *Ph. cepolae*, however, in which YAMAGUTI has failed to discover them, is provided with this pair. Caudal rami are missing at least in the full-grown adult.

Phrixocephalus triangulus Wilson, 1917
(Figs. 1 & 2, Pl. XX, Figs. 1 & 2)

Wilson 1917, pp. 76–77, Pl. 9, Figs. 80–84, Pl. 10, Fig. 85; 1923, p. 14.

Specimens examined: Total number 5, on *Neopercis multifasciata* (Döderlein), in the vicinities of Hayama, Sagami Bay. They are lodged in the Biological Laboratory of His Imperial Majesty. Particulars of their records are as in the following tables:

Catalogue No. in B.L.H.I.M.	Parasite	Length of host (from snout to tail)	Side of the infected eye of host	Locality	Depth	Date
Crust. No. 10	Adult, ovigerous	4.8 cm.	right	West of Kamesiro	50 m.	July 13, 1952
	Young, non-ovigerous	3.4 cm.	〃	〃	〃	〃
Crust. No. 17	Adult, ovigerous	7.0 cm.	left	Kannonzuka-dasi, Ama-daiba	60–80 m.	March 18, 1954
Crust. No. 736	Adult, ovigerous	6.7 cm.	right	Maruyama-dasi, Ama-daiba	5 m.	September, 29, 1953
Crust. No. 666	Young, non-ovigerous	3.0 cm.	〃	〃		July 21, 1952

Measurements in mm.

Catalogue No.	No. 10		No. 17	No. 736	No. 666
	Adult	Young			
Length of head and neck	3.23		4.15	4.23	3.00
Diameter of head processes			5.00	5.00	2.86
Length of trunk	4.16	3.38	4.69	5.85	3.78
Width of trunk				2.62	2.08
Thickness of trunk	2.15		3.62	3.08	1.77
Length of egg string	3.16		3.85	6.31	
Figure No.	Fig. 1, C; Pl.XIX,Fig.2			Fig. 1, A, B, D; Pl.XIX,Fig.1	Fig. 2, A–J

Distribution: Japan. Type locality: Owari Bay, on the same fish as named above (Wilson 1917). Wilson's later record (1923) from unknown host in Tierra del Fuego, Argentina is rather doubtful, since the only specimen was without the head and neck.

As the original description was based on an abnormal specimen, I have prepared a new one.

Adult female: Body whitish yellow to reddish brown in formalin, egg strings yellowish to brownish. Neck making a right angle with trunk and twisted nearly 90° around body axis.

Head truncate anteriorly and with a single pair of profusely branched lateral processes; branching, on the whole, dichotomous. Branches of two sides overlap on ventral side, but not on dorsal side, a wide medio-dorsal space remaining uncovered by them. Neck slender, elongate cylindrical, without any trace of articulation; portion posterior to thoracic horns strongly chitinized, slightly

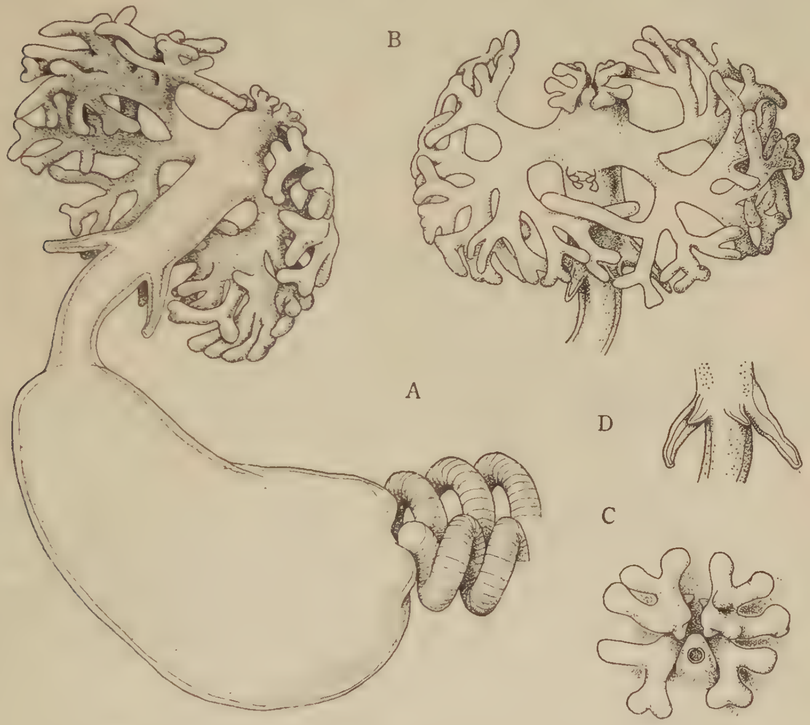

Fig. 1. *Phrixocephalus triangulus* WILSON.
A, cat. No. 736, head and neck in dorsal view, trunk in side view; B, same, head and neck, ventral view; C, cat. No. 10, antennae and oral tube; D, cat. No. 736, thoracic horns, ventral view. A, B, D ×10, C ×27.

narrower than anterior portion, and a trifle curved toward the right. Thoracic horns simple, present at about the middle of neck length; dorsal pair longer, placed on lateral sides, ventral pair close to mid-ventral line and much shorter. Neck inserted to extreme anterior end of trunk somewhat eccentrically and to the right side of midline. Trunk wider and thicker posteriorly than anteriorly, with dorsal face slightly concave and ventral face strongly convex. Caudal

margin quadrate in dorsal aspect; gonopore regions forming round lateral bulges, and interposing a slightly raised, circular median area which represents rudimentary abdomen. Egg strings attached on dorsal level and just inside the lateral bulges. Caudo-ventral region forms a large round swelling which continues forward to general ventral surface of trunk.

First antennae divided from the very base into 3 apically round, claviform

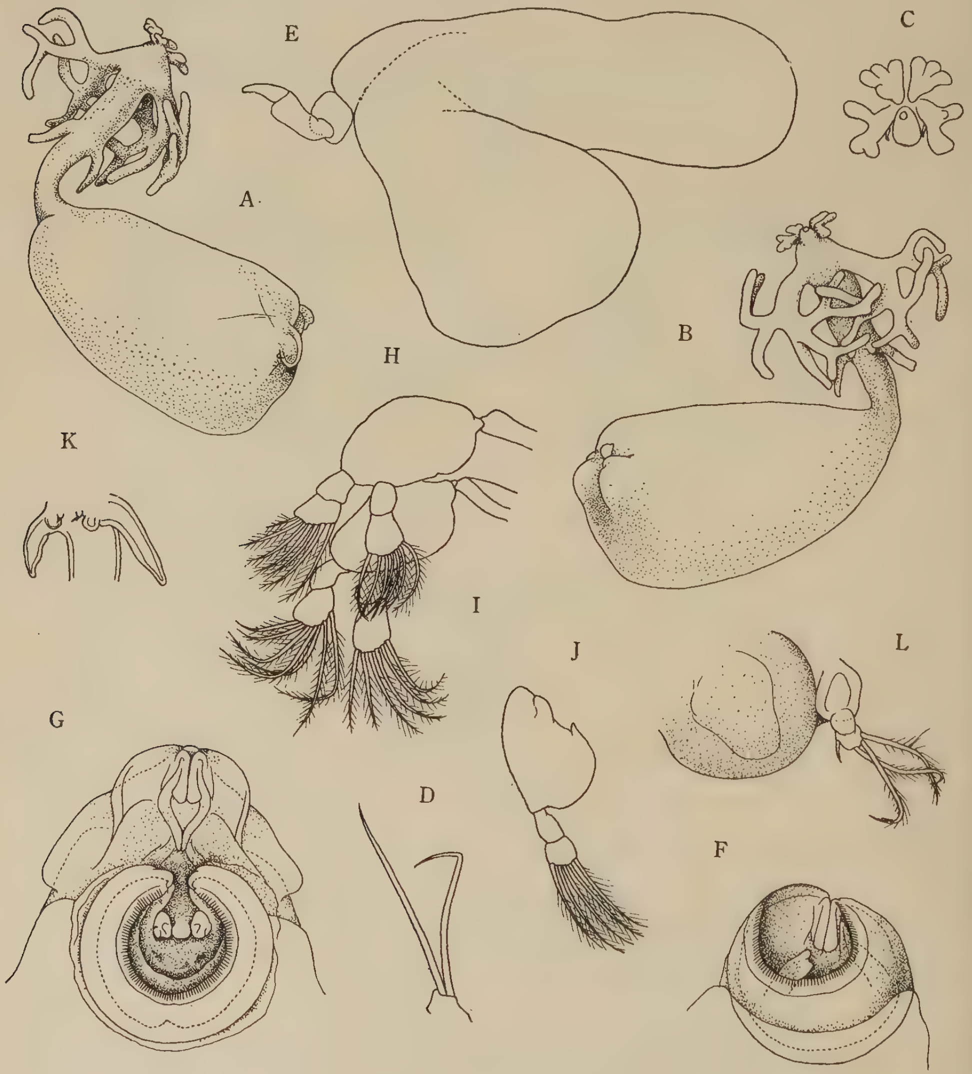

Fig. 2. *Phrixocephalus triangulus* Wilson, young female, cat. No. 666. A, head and neck in dorsal view, trunk in side view; B, head and neck in ventral view, trunk in side view; C, antennal region; D, maxilla; E, 2nd antenna and maxilliped; F, oral tube; G, same, with labrum and labium detached, showing mandibles enclosed within; H, 1st leg; I, 2nd leg; J, 3rd leg; K, thoracic horns and 4th legs; L, ventral thoracic horn and 4th leg. A, B ×10, C, K ×19, D, E, H–J, L ×170, F, G ×340.

branches; posterior branch with a small conical, basal process on posterior side and anterior branch with a similar one on inner side; round, inconspicuous protuberances discernible on the surface of branches also. Second antennae bifurcate, having posterior branch again shallowly bifurcated. First 2 pairs of swimming legs close together and just behind the lateral processes of head, 3rd pair situated midway between these and thoracic horns, and 4th pair just inside ventral horns. Caudal rami absent.

Younger female: Head processes not so strongly branched as in adult and not extending forward. Ventral thoracic horns in the form of round knobs. Trunk triangular, with dorsal face only slightly convex. Caudal end angular at dorsal angle, well round at ventral angle, and quadrate in dorsal aspect; lateral corners represented by bulges at the bases of egg strings which are rudimentary. Neck inserted to the anterior angle of trunk eccentrically to the right as in adult.

First antennae tripartite, 2nd bipartite, with posterior branch only slightly forked. Leg rudiments relatively larger in size than in full-grown adult.

Phrixocephalus cepolae YAMAGUTI

(Fig. 3, Pl. XX, Fig. 3)

YAMAGUTI 1939, pp. 482–483, Pl. 32, Fig. 183, Pl. 33, Figs. 186–188.

A single specimen, on the left eye of *Cepola schlegeri* BLEEKER, at Owase, by Mr. K. SUZUKI.

This is the second record of the species. The type described by YAMAGUTI was found on the same host from Toyama Bay.

Head processes, transverse diameter 4.30, dorso-ventral diameter 3.08, head and neck, length 3.46, trunk, length 6.00, thickness in posterior region 2.85, egg string, length 7.70 (all in mm.); yellowish brown in alcohol, with whitish head processes, brown antennae and yellowish egg strings; 4th segment region together with its horns very strongly chitinized.

Head narrow in width, with anterior border arched, bearing 5 major trunks of processes on the right and 6 on the left, all ramifying into minor branches. Ramification not necessarily dichotomous but irregular. Apices of branches from either side meeting and overlapping both dorsally and ventrally. Neck cylindrical, somewhat curved ventrally, with its portion behind thoracic horns slenderer. It turns its dorsal side to right side of trunk, to which it is attached a short distance behind the anterior end. Dorsal thoracic horns divided into 3 branches on the right, but into 2 branches with bifid apex on the left; ventral horns shorter, pointed, with a short triangular, anteriorly directed branch on the right and a quadrate basal one on the left. Trunk swollen, banana-shaped,

Fig. 3. *Phrixocephalus cepolae* YAMAGUTI.

A, head and neck in ventral view, trunk in ventro-lateral view; B, head and neck in dorsal view, trunk in dorso-lateral view; C, head; D, antennae, lateral view; E, thoracic horns, dorsal view; F, same, ventral view; G, same, left side view. A, B ×7.5, C–G ×15.

convex ventrally and concave dorsally. Abdomen present at dorso-posterior angle of trunk as a low, circular swelling which is confluent forward with trunk surface, but more or less distinctly demarcated backward. It is higher than gonopore swellings, which are conspicuous on the right but inconspicuous on the left. Egg strings divergent, loosely coiled.

Antennae not intricate in ramification. First pair divided into anterior and posterior rods, the latter more or less erected over head surface; each rod again splits into 2 round tips. Second pair with 2 branches, one directed laterally and the other posteriorly, both of these shallowly bifid at their apices. Maxillipeds present. First 2 pairs of legs close to head, 3rd pair at about the middle between these and thoracic horns, and 4th pair just inside the bases of ventral thoracic horns.

Remarks: As mentioned before, YAMAGUTI's description on the thoracic legs is inadequate. These are the same in number and similar in structure to what are found in *Ph. triangulus.* His 2-segmented endite on the 2nd antenna is nothing but the maxilliped.

Phrixocephalus umbellatus n. sp.

(Figs. 4–7, Pl. XX, Fig. 4)

Specimens examined: Total number 6, all adult, on *Callionymus richardsoni* BLEEKER. Particulars of their records are indicated in the following tables:

Catalogue No.	Number of specimens comprised	Localities	Collector	Date
18	2	off Tyôsi, Tiba Pref.	myself	April 9, 1943
32	2	off Tuiyama, Hyôgo Pref., 80 fathoms deep	K. Matsubara	May 12, 1943
318	1	off Owase, Mie Pref.	K. Suzuki	unnamed
321	1	off Tyôsi, Tiba Pref.	myself	April 9, 1943

Measurements in mm.

Catalogue No.	No. 18		No. 32		No. 318
	Holotype	Paratype	Dextral	Sinistral	
Transverse diameter of head processes	7.70	6.61	4.46	3.48	
Dorso-ventral diameter of head processes	6.39	5.70	3.92	2.04	
Length of head and neck	6.60	5.58	4.62	2.60	3.08
Length of trunk	6.46	6.15	5.54	3.93	4.31
Thickness of trunk		4.46	2.54	2.13	2.62
Width of trunk		3.16	2.54		2.23
Length of egg string			7.93	3.67	7.30
Figure No.	Fig. 4			Fig. 5	Fig. 6; Pl.XX,Fig.4

One of the specimens from No. 18 has been selected as holotype, others being made paratypes. Of these, No. 321 has been mutilated during preservation.

Holotype: Body brownish in preservative, with head processes much paler in color and antennal branch darker; egg strings yellowish brown. Neck meets trunk nearly at right angles and is twisted so as to turn its left side to the dorsal surface of latter.

Head produced and more or less tubercular on anterior margin, continuing back to the ventral face of neck without distinct demarcation. Lateral processes in 2 pairs, each being divided from the very base into a few branches which shoot out many branchlets; these overlapping one another all around head circumference. Neck relatively long, with the region posterior to thoracic horns much narrowed, curved ventrally nearly at right angles and inserted to trunk some

Fig. 4. *Phrixocephalus umbellatus* n. sp.
A, holotype, head and neck in ventral view, trunk in side view; B, paratype, head; C, holotype, thoracic horns, dorsal view. ×10.

distance behind anterior end. Thoracic horns present at posterior 1/3 of neck; dorsal pair longer, locating on either side of neck, ventral pair close to midline; both pairs with 5 or 6 branches. Trunk about as long as head and neck combined together, rather thick, with concave dorsal and convex ventral faces. Fore end narrow, triangularly round. Caudal end widening, well round, and

swollen ventrally. Swellings lateral to gonopores rather low, interposing a circular, slightly bilobed abdomen. The latter attaches to trunk somewhat below dorso-posterior angle and exhibiting an angularly round appearance in lateral aspect. Egg strings partly lost.

Two pairs of antennae coralliform and indistinguishable from each other owing to intricate ramification. First 2 pairs of legs close to head, 3rd pair about halfway between these and 4th pair, which is just inside the ventral thoracic horns.

Paratype: Another individual contained in catalogue no. 18 (Fig. 4, B)

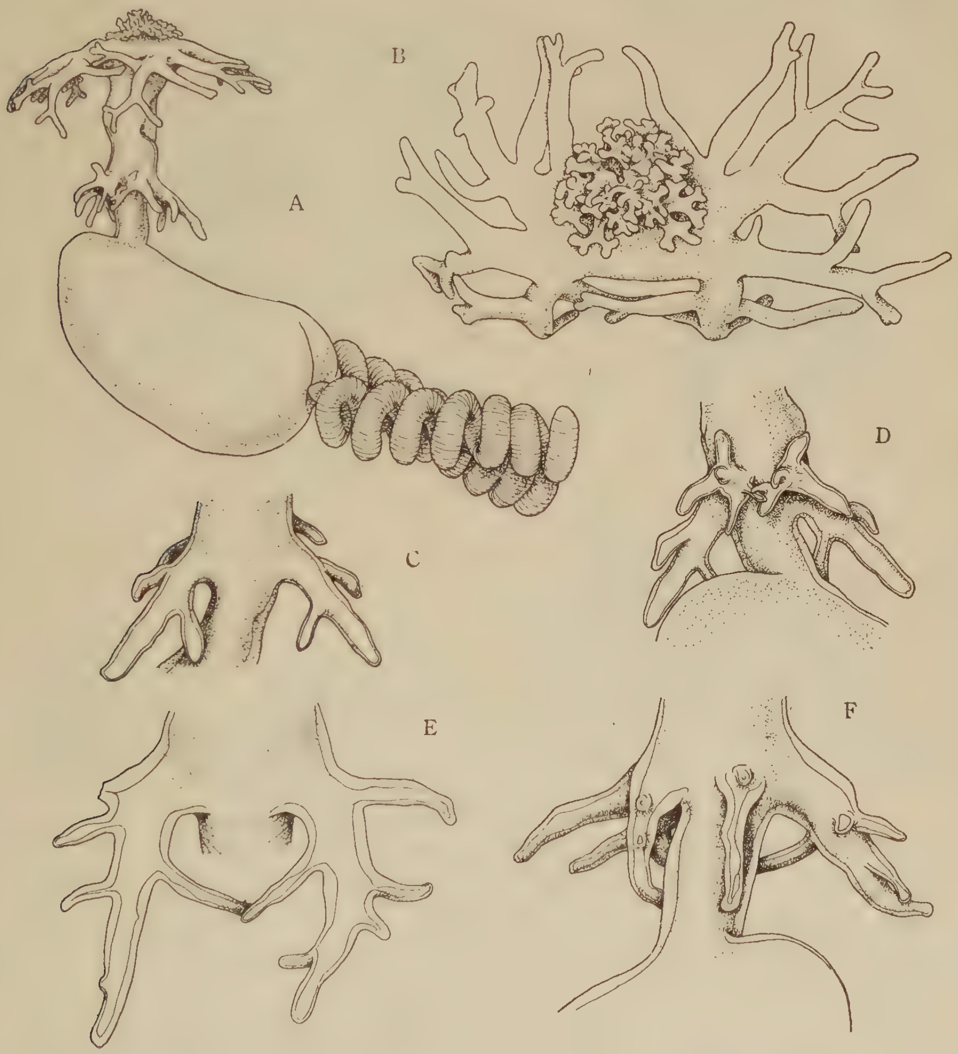

Fig. 5. *Phrixocephalus umbellatus* n. sp., cat. No. 32. A, head and neck in ventral view; trunk in side view; B, head; C, thoracic horns, dorsal view; D, same, ventral view; E, same of another specimen, dorsal view; F, same, ventral view. A ×10, B–F ×19.

shows character similar to the holotype except having head processes somewhat less extensive.

No. 32 includes 2 specimens twisted in opposite directions. Sinistral female (Fig. 5, A) has head processes not so strongly ramified as in other specimens, anterior and posterior main trunks issuing fewer branches. Dorsal thoracic horns with 2 accessory branches, and ventral horns divided from the very base into 5 divergent branches. Dorsal surface of trunk nearly flat. The other female which is dextral has head processes more strongly divided. Dorsal thoracic horns with 4 or 5 branches, whereas ventral horns in the form of simple hooks and bearing small tubercles instead of branches. Trunk shows stronger curvature than in sinistral female. Egg tubes slightly divergent in both cases.

No. 318 (Fig. 6): Head processes not distinctly divisible into anterior and posterior pairs, but consisting of 7 trunks, each sending out a few branches. Neck with an additional pair of short simple processes a short distance behind

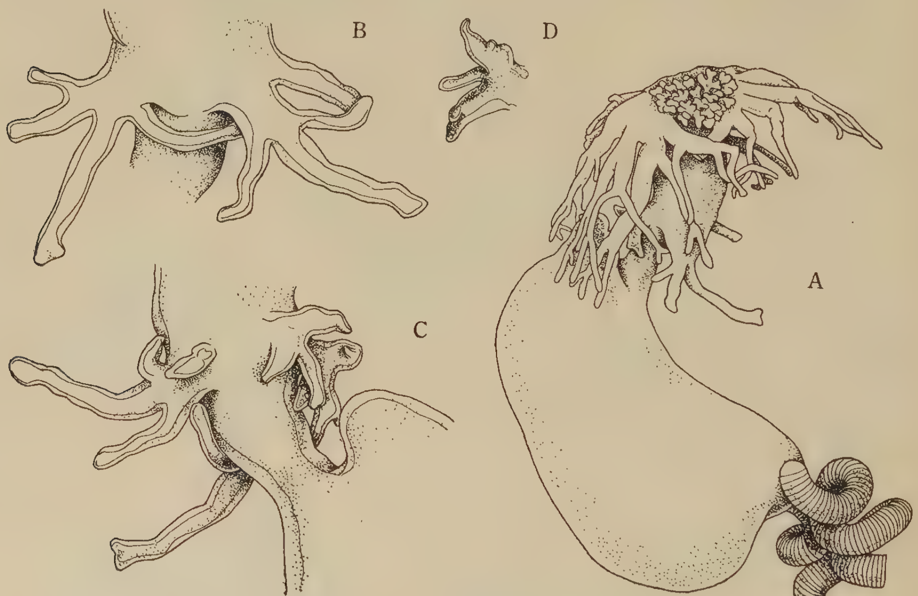

Fig. 6. *Phrixocephalus umbellatus* n. sp., cat. No. 318.
A, head, neck and trunk in lateral view; B, thoracic horns, dorsal view; C, same, lateral view; D, ventral thoracic horns of left side. A ×10, B–D ×19.

head processes, arranged one on each side of mid-ventral line. Posterior region of neck curved ventrally and making an obtuse angle with trunk; its axis twisted to the right only a trifle, with dorsal side facing the same side of trunk approximately. Dorsal thoracic horns divided into 1 long and 3 short branches on the right, 1 long and 2 short ones on the left; ventral horns far shorter, with 4 branches on the former, 3 on the latter; anterior and postero-lateral branches of left ventral horn with an accessory tubercle.

No. 321 (Fig. 7): Injured specimen, broken in 2 pieces at the junction of neck and trunk. Head processes divisible into anterior and posterior groups, each of which is forked into 3 branches almost from base. Dorsal thoracic horns with 3 long and 1 rudimentary branches on the left, 2 long and 2 short

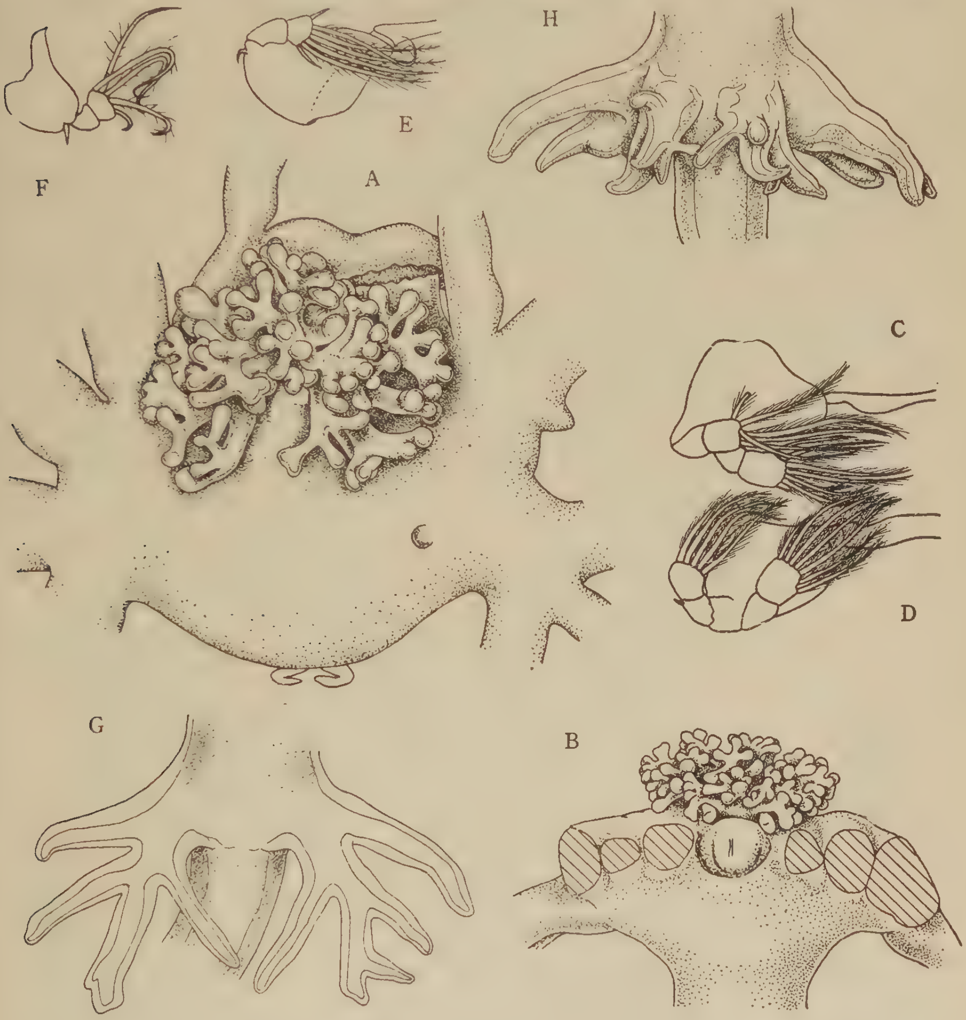

Fig. 7. *Phrixocephalus umbellatus* n. sp., cat. No. 321. A, head; B, same, dorsal view; C, 1st leg; D, 2nd leg; E, 3rd leg; F, 4th leg; G, thoracic horns, dorsal view; H, same, ventral view. A ×27, B, G, H ×19, C–F ×170.

ones on the right, all shooting out on one plane. Ventral horns forked into 5, long and short, divergent branches. First 2 leg rudiments crowded just behind head region, biramous, 3rd legs about halfway between these and thoracic horns, and 4th just inside ventral thoracic horns; last 2 legs uniramous.

Remarks: The present species may be distinguished from the hitherto known species of the genus first by the extensive ramification of the antennal

processes, and second by having numerous branches on the thoracic horns. The present collection which has come from three localities gives a good example of the variability of *Phrixocephalus* within a species.

Phrixocephalus longicollum n. sp.

(Fig. 8)

A single specimen, on *Callionymus richardsoni* Bleeker, off Tyôsi, Tiba Prefecture, by myself, April 9, 1943.

Body brownish in alcohol, with well-chitinized integument. Head and neck, length 7.31, trunk, length 4.08, thickness 1.92, width 2.04 (all in mm.).

Head has anterior border largely round except bearing a slight median projection. Lateral processes in 2 pairs, each ramifying almost from base into a few numbers of thick branches which are subdivided repeatedly into thinner ones. Branches of both sides overlap dorsally as well as ventrally. Neck elongate, less than twice as long as trunk, rather thick, but much narrowed behind thoracic horns which are present at a posterior quarter of its length. It is slightly curved dorsally and continues to the extreme anterior end of trunk

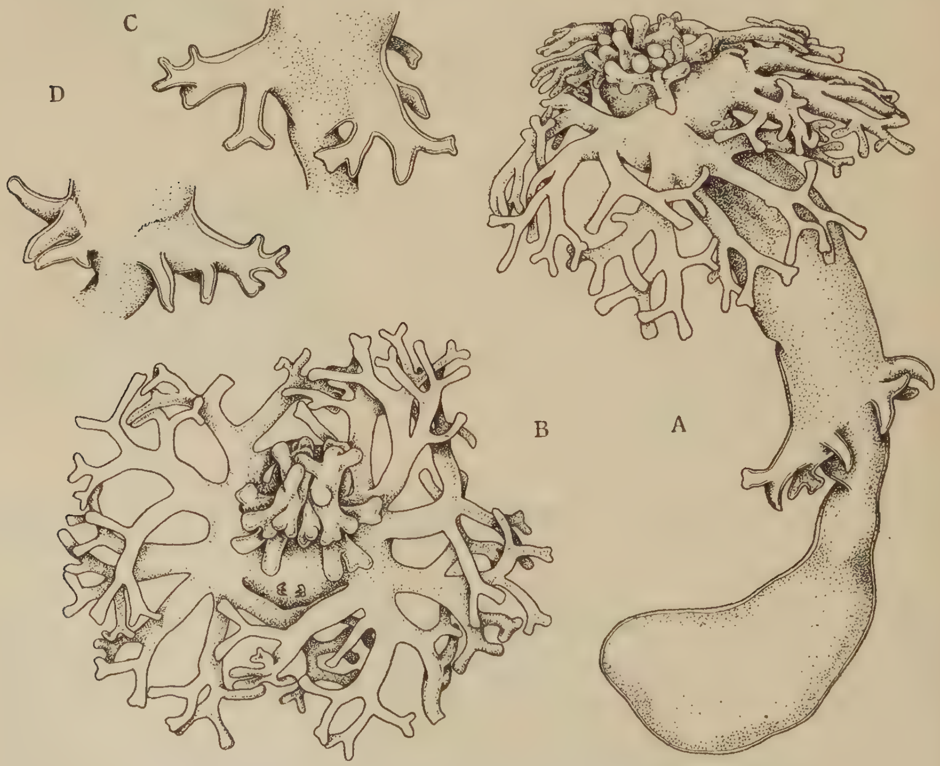

Fig. 8. *Phrixocephalus longicollum* n. sp. A, head and neck in ventral view, trunk in lateral view; B, head; C, thoracic horns, dorsal view; D, same, ventral view. ×10.

without distinct demarcation. Dorsal pair of thoracic horns sending out a few short branches; ventral pair further shorter, bifid on the right, simple on the left. Trunk a little curved dorsally and widening slightly backward. Abdomen is a large round bulge at posterior end of trunk on mid-dorsal line, but rather indistinctly demarcated. Oviducal pores present some distance forward from the end of trunk without forming any swelling. Egg sacs missing.

First antennae composed of 2 rods, one directed forward and the other backward, these splitting into several branches with tuberculiform apices. Second antennae similar in appearance, but less strongly branched, consisting of laterally and posteriorly projecting branches which are subdivided. First 2 pairs of legs close to head, 3rd pair at about the middle between these and thoracic horns; 4th legs missing.

Remarks: The present specimen may be distinguished from *umbellatus*, which is parasitic on the same host species, by the less complicated ramification of antennae, by rather simpler ventral thoracic horns, and by the relative length of the neck to the trunk. The specimen seems to be in a somewhat young stage, since its trunk bears no trace of egg strings. As the measurements indicate, however, the head and neck are far longer than in any of the full-grown adults of *umbellatus*. When this fact is taken into consideration, it will be evident to anyone that the present specimen is distinct from that species.

Phrixocephalus curvatus n. sp.

(Fig. 9)

A single specimen, on an undetermined species of flat-fish, off Tyôsi, Tiba Prefecture, by myself, June 10, 1943.

Body brownish in color in alcohol; from head to curving point of neck 4.23 long, from same to neck base 1.69 long, head processes, transverse diameter 5.61, dorso-ventral diameter 5.15, trunk, length 4.85, thickness 3.18 (all in mm.).

Head round in front, with ventral area rather wide and bearing a few tubercles on either side. Lateral processes consist of 4 trunks on the right and 3 on the left, all of these profusely branching; branches overlap one another around the head, leaving a wide ventro-median sinus free from them. Neck curves ventrally at right angle behind its center and is much narrowed. It is twisted, further, around its axis rightward for some angle, so that its ventral surface, which is opposite to the dorsal side of trunk in anterior region, corresponds to the right side of trunk in posterior region. It is inserted to trunk perpendicularly a short distance behind extreme anterior end. Thoracic horns well developed and branched. Dorsal member of left side has 3 long proximal and 3 short distal branches and bilobed tip, outer proximal branch being deeply bipartite; that of the right has 3 long and 1 short basal branches and tripartite

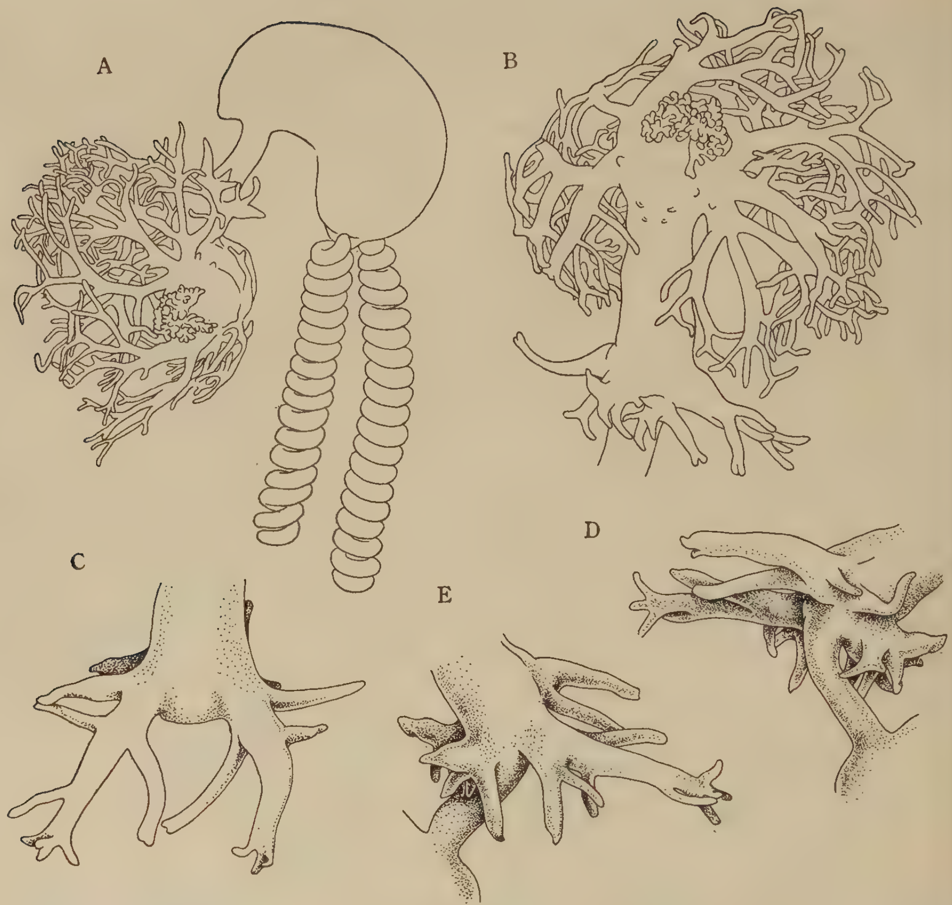

Fig. 9. *Phrixocephalus curvatus* n. sp. A, head and neck in ventral view, trunk in side view; B, head and neck, ventral view; C, thoracic horns, dorsal view; D, same, right side view; E, same, left side view. A ×6.5, B ×9, C–E ×10.

apex. Left ventral horn forked into 5 short divergent branches, most external one of these ending in bifid apex; right horns 4-branched, postero-laterally directed branch bearing a tiny accessory one. Trunk strongly curved like a comma, with dorsal surface concave and much shorter than highly convex ventral surface. Anterior end angular; posterior end swollen, well-round and bearing a low, hemispherical abdomen near dorsal surface as well as a pair of round, feeble oviducal bulges. Egg strings long and tightly coiled.

Two pairs of antennae well-chitinized, darker in color than adjoining region of head, and profusely ramified. They are indistinguishable from each other owing to the intricacy of fine, tuberculiform branchlets.

Remarks: The present species is closely allied to *umbellatus* described before in the ramification of the antennae, in the constitution of thoracic horns and in that the neck is inserted to the trunk a short distance behind the anterior

end, but may be distinguished by the stronger curvature of the neck and by the twisting of its axis, as well as by the ventral surface of anterior neck region being uncovered by head processes.

Phrixocephalus arboreus n. sp.

(Fig. 10)

Two adult specimens, on *Tanakias kitaharae* (JORDAN & STARKS) at Tyôsi, by myself, June 9, 1943. Holotype deprived of egg tubes; the other specimen mutilated, with head and neck missing.

Fig. 10. *Phrixocephalus arboreus* n. sp. A, head, neck and trunk in dorso-lateral view; B, head and anterior portion of neck; C, antennae, antero-ventral view; D, same, antero-dorsal view; E, 1st leg; F, 2nd leg; G, 3rd leg; H, thoracic horns, dorsal view; I, same, ventral view. A, B, H, I ×10, C, D ×220, E–G ×170.

Holotype: Brown in color. Head processes, transverse diameter 6.47, antero-posterior diameter 5.20, head and neck, length 6.24, trunk, length 4.00, thickness 2.47, width 2.31 (all in mm.).

Head has front arched and trilobed, with median lobe somewhat more prominent than lateral lobes; these latter provided at outer angle with a small round papilla. Lateral processes in 2 pairs; each of these divided nearly from base into 2 branches which send out again a few short branchlets. Neck straight, much longer than trunk, narrowed in posterior region and making a right angle with trunk, to whose anterior end it is inserted. Its dorsal side opposite to the same side of trunk. Accessory horns at about posterior 1/3 of neck length. Dorsal horns divided into 4 long spines, outer basal one of these being bipartite on the left; ventral horns much shorter, composed of 4 stout and 1 rudimentary spines on each side. Trunk not much curved, with dorsal surface showing a slight concavity. Anterior end not projecting, smoothly round; posterior end also well round, with gonopore swellings rather inconspicuous. Abdomen nearly obliterated, represented merely by slightly raised, circular area at caudo-dorsal angle of trunk.

Two pairs of antennae distinct from each other. First pair elongate antero-posteriorly, ending forward in several short divergent, claviform branches and backward in 2 longer branches which, on their side, are more or less forked or tuberculated. Second pair shoot out 3 divergent, laterally directed, claviform branches, posteriormost of these having lobed tip on both sides. Maxillipeds distinct. First 2 pairs of legs crowded together near anterior end of neck, biramous, 3rd pair about halfway between these and thoracic horns, uniramous; 4th missing. Egg tubes missing.

Remarks: The present species appears to be close to *longicollum* described above in having the elongate neck and in the relatively simple branching of antennae, but is different in the disposition of thoracic horns which are stouter and in having the head processes more sparingly branched. It also resembles *Ph. diversus* Wilson in the constitution of antennal and cephalic processes. The neck of the new species, however, is relatively much longer than in that species, and is inserted to the extreme anterior end of trunk unlike in *diversus*.

Phrixocephalus alatus n. sp.

(Fig. 11)

A single specimen, on the left eye of the young individual of *Pagrosomus major* (T. & S.) (6.0 cm. long), in the vicinity of Usibuse, Suruga Bay, by Mr. K. Ooyama.

Body pale yellowish brown in alcohol, head processes, transverse diameter 4.83, antero-posterior diameter 3.67, head and neck, length 3.69, trunk, length

5.54, thickness 2.69, width 2.23, egg strings, length 5.00 (all in mm).

Head with a slight bulge on each antero-lateral angle. Lateral processes in 2 pairs, each being divided nearly from the base into a few branches which shoot out secondary ones to expand like a pair of wings. Branches of 2 sides meet and overlap on ventral side of head, but not on dorsal side, a wide median sinus remaining free from them. Neck comparatively short, joined with trunk at right angles, and with dorsal surface twisted to that of trunk for an angle less than 90°. Thoracic horns present somewhat behind the middle of neck. Dorsal horns short in comparison with their thickness, tripartite on both sides; ventral horns again shorter, bipartite on the right and tripartite on the left.

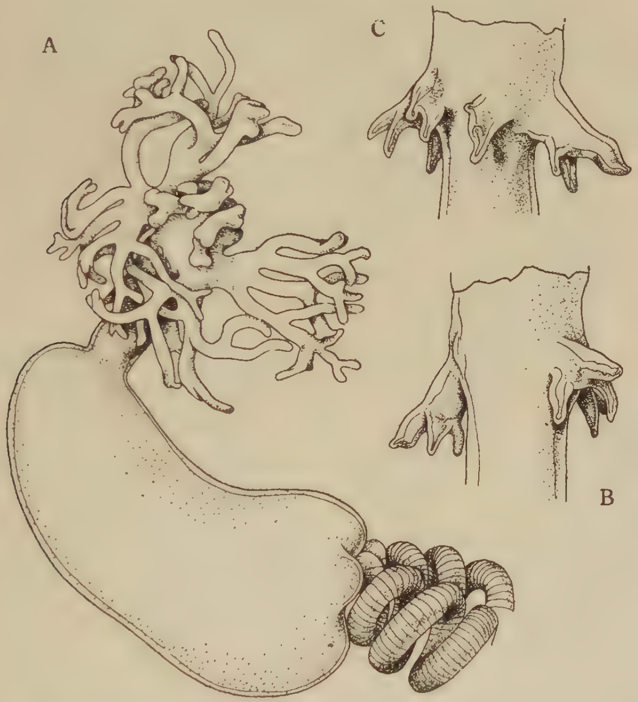

Fig. 11. *Phrixocephalus alatus* n. sp. A, head and neck in ventral view, trunk in side view; B, thoracic horns, dorso-lateral view; C, same, ventro-lateral view. A ×10, B, C ×19.

Trunk relatively long, sausage-shaped, insensibly widening caudally, and showing a slight dorsal concavity. Anterior end round, somewhat extending beyond the insertion point of neck; posterior end sinuate on the median and with angularly round lateral corners. Region where each egg string attaches forming round bulge. Abdomen prominent, higher than that bulge, trapezoid and somewhat bilobed in dorsal aspect, though well round in lateral aspect, and confluent forward with trunk surface. Egg sacs only slightly shorter than trunk, somewhat loosely coiled.

First antennae in the form of short longitudinal rods, ending in 3 or 4 tubercles forward and in 2 or 3 backward. Second antennae also rod-like, directing postero-laterally, with bilobed tip, and with or without outer basal tubercle. First 2 pairs of legs close to head, 3rd at about the middle between these and 4th, which are present just inside the base of ventral thoracic horns.

Remarks: The present species may be characterized by having the relatively simple antennae, sparingly branched head processes, short neck, and plump thoracic horns.

Phrixocephalus vipereus n. sp.

(Fig. 12, Pl. XX, Fig. 5)

A single specimen, on the right eye of *Branchiostegus auratus* (Kishinouye), off Owase, by Mr. K. Suzuki. During the course of dissection it was broken into 2 at the junction of neck and trunk.

Trunk and egg strings whitish yellow in preservative, head precesses and neck paler in color; head processes, transverse diameter 10.2, dorso-ventral diameter 7.14, head and neck, length 5.08, trunk, length 8.08, thickness in anterior region 2.77, same in posterior region 4.08, width at posterior end 3.31, egg tube 8.85 (all in mm.).

Head truncate in front, sending out 6 main trunks of processes from either side. These trunks bring forth again rather long, tortuous branches which form as a whole an extensive system of strings entangled one with another; these extending farther and more intricate on the right than on the left. Neck comparatively short and curved ventrally in posterior region. Dorsal thoracic horns stout, with 2 accessory branches; apex and one of branches deeply bifurcate on the left, but rather shallowly on the right. Ventral horns short, divided into 5 unequal, divergent branches near the base. Trunk curved dorsally showing strong concavity. Anterior end well round and extending some distance beyond the insertion point of neck. Posterior end rectangular at dorsal angle in lateral aspect, continuing downward to enormous ventral swelling, truncate in dorsal aspect, with both corners represented by round protuberances lateral to gonopores. Abdomen distinct, trapezoid, occupying less than 1/3 of trunk width, slightly bilobed on the median and confluent forward with dorsal surface of trunk. Egg tubes long, loosely coiled.

First antennae branched in the form of V, both arms of which end in 3 tubercles; posterior arm erected over head surface. Second antennae also forming V, with arms directed laterally and posteriorly; lateral arm bipartite, whereas posterior arm tripartite, all with claviform tips. First 2 pairs of legs crowded together near anterior end of neck, 3rd pair far back from the middle of neck and close to thoracic horns, all setaceous; 4th pair represented by minute non-

Fig. 12. *Phrixocephalus vipereus* n. sp. A, head and neck, ventral view; B, thoracic horns, dorsal view; C, same, ventral view; D, trunk, lateral view; E, posterior end of trunk, dorsal view; F, antennae. A–E ×10, F ×19.

setaceous papillae, placed just inside the ventral horns.

Remarks: Of all the characters, by which the present species can be distinguished from others, the most important is the development of extravagant head processes.

Phrixocephalus crassus n. sp.

(Fig. 13)

A single specimen, on *Hoplichthys longsdorfi* (C. & V.), off Minabe, Wakayama Prefecture, at a depth of 100–200 fathoms, by Mr. S. SAKAGUTI, May, 1943. It was broken during preservation into 3 pieces: head with a portion of neck, the rest of neck, and trunk.

Yellowish brown in preservative; head processes, transverse diameter 5.00, dorso-ventral diameter 4.00, head with neck piece attached to it 1.39 long, neck, middle piece 2.08 long, its portion attached to trunk 0.62 long, trunk, length 3.77, width 2.08, thickness 2.69, egg tube 5.08 (all in mm.).

Head rather broad, with anterior margin irregular. Lateral processes

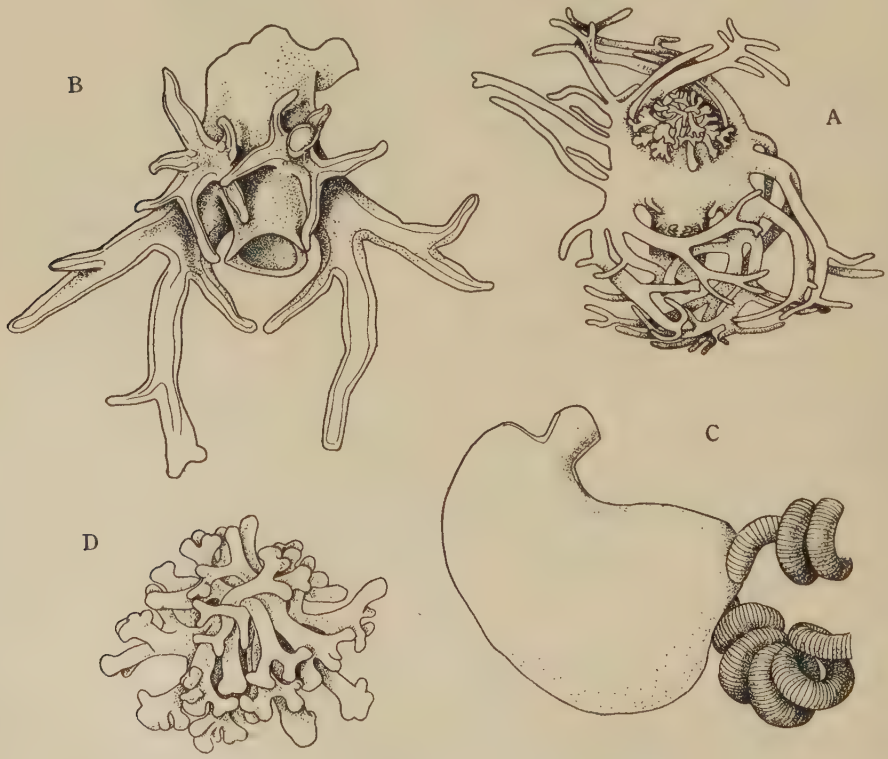

Fig. 13. *Phrixocephalus crassus* n. sp. A, head and neck, ventral view; B, thoracic horns, ventral view; C, trunk, side view; D, antennae. A, C ×10, B ×19, D ×27.

divisible into dorsal and ventral groups on either side, each sending out a relatively few number of branches. These extend chiefly forward and backward to overlap one another, but not on either lateral side, where they are rather scanty in number. Head furnished with an additional pair of short simple processes, one at each ventro-lateral angle, and with another similar, but feebler pair somewhat behind and just outside the 1st leg rudiments. Neck slender, inserted to trunk some distance behind anterior end. Dorsal pair of thoracic horns long and stout, tripartite, with outer branch accompanying a secondary one, central branch of right side with similar secondary one near apex which is bifid; ventral pair short, divided from the very base into 6 divergent branches. Trunk stumpy, short in comparison with its thickness, and increasingly thicker backward. Dorsal surface concave in anterior region, but slightly convex in posterior region; ventral surface highly convex. Both anterior and posterior ends with round dorsal angle and enormous ventral swelling. Egg sacs attached to trunk somewhat below dorsal surface and not accompanying surface bulges at their bases. Abdomen trapezoid, surpassing posterior border of trunk.

Two pairs of antennae indistinguishable from each other, complicatedly branched, forming a bouquet of numerous narrow ribbons ending in lobate apices. First 2 pairs of legs close to each other at anterior end of neck, 3rd not discernible, and 4th present just inside thoracic horns.

Remarks: The present species is rather close to *umbellatus* described before in the constitution of thoracic horns, in that of the head processes, and in that the neck is inserted to the trunk behind its anterior end. They are somewhat different in the ramification of the antennae and in the sparingly branched head processes of the present species which are distributed chiefly on the anterior and posterior sides. Although these differences may be of minor importance, it seems to me preferable to separate them as distinct species chiefly on the ground that they are parasitic on the different host species.

Phrixocephalus reniformis n. sp.

(Fig. 14, Pl. XX, Fig. 6)

A single mutilated specimen, on *Calliurichthys japonicus* (HOUTTUYN), at Hayama, Sagami Bay, by the staff of the Biological Laboratory of His Imperial Majesty, labeled "crustacea No. 768" and to be lodged there. Neck broken at its posterior end.

Pale yellowish brown in color; head processes, transverse diameter 5.39, dorso-ventral diameter 4.31, head and neck 2.31 long, neck piece remaining to trunk 0.35 long, trunk, length 4.54, width 2.08, thickness 2.54, egg tube 4.15 long (all in mm.).

Head with anterior border produced, more or less tuberculated, and bearing

a pair of short bifurcate processes, disposed one on each side of 1st antennae. Lateral processes divided into 3 groups on either side; central pair not much branched, whereas other 2 pairs forked into 3 almost from the base and profusely branched further distally. Branches overlapping all around head. Neck relatively short, much narrowed behind thoracic horns. Dorsal thoracic horns asymmetrical,

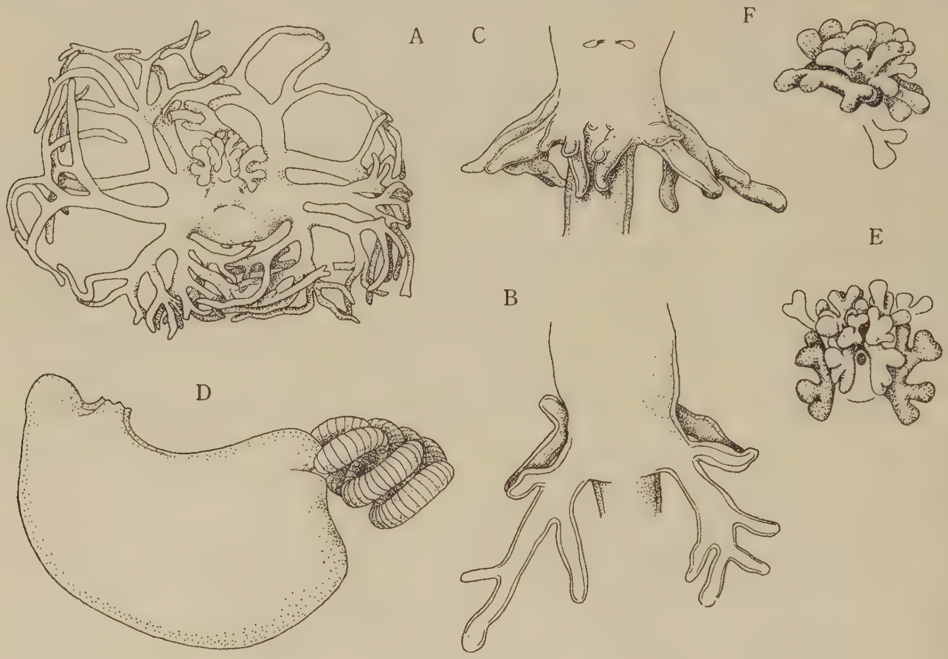

Fig. 14. *Phrixocephalus reniformis* n. sp. A, head; B, thoracic horns, dorsal view; C, same, ventral view; D, trunk, lateral view; E, antennae; F, same, side view. A, D ×10, B, C, E, F ×19.

longer on the left, bearing 2 outer and 1 inner branches, but with an additional outer one on the right. Ventral horns composed of 2 branches disposed in V-shape, each accompanying at the base a short tuberculiform accessory branch; outer branch in contact with outer basal branch of dorsal horns of corresponding side at their apices. Trunk reniform, narrowing forward; dorsal surface gracefully concave, ventral surface highly convex. Anterior end protrudes beyond the insertion point of neck as a small round bulge which is quadrate and bilobed in dorsal view. Posterior end rectangular at dorsal angle, well round at ventral angle. Dorso-posterior border more or less quadrate and trilobed, central lobe corresponding to abdomen, trapezoid, and confluent forward with general surface; lateral lobes representing conical bulges placed just outside oviducal pores. Egg tubes divergent.

Two pairs of antennae distinct from cach other. First pair extends antero-posteriorly and sends off short forked branches which are erected over the surface

ending in claviform apices. Second pair just outside the 1st pair, divided into 4 divergent, claviform branches. First 2 pairs of legs close together at anterior end of neck, 3rd far apart from these and closer to 4th which are just inside the bases of ventral thoracic horns.

Remarks: The present species may be characterized, above all things, by the constitution of antennae and thoracic horns.

References

1. WILSON, C. H., 1908. North American parasitic copepods: A list of those found upon the fishes of the Pacific coast, with descriptions of new genera and species. Proc. U. S. Nat. Mus., Vol. 35, pp. 431–481, Pls. 66–83.
2. ———, 1917. North American parasitic copepods belonging to the Lernaeidae with a revision of the entire family. Ibid., Vol. 53, pp. 1–150, Pls. 1–21.
3. ———, 1922. Parasitic copepods from Japan, including five new species. Ark. f. Zool., Vol. 11, No. 10, pp. 1–17, Pls. 1–4.
4. ———, 1923. Parasitic copepods in the collection of the Riksmuseum. Ibid., Vol. 15, No. 3, pp. 1–15, Pls. 1–2.
5. YAMAGUTI, S., 1939. Parasitic copepods from fishes of Japan: Part 5, Caligoida, III. Vol. Jubil. pro Prof. S. Yoshida, Vol. 2, pp. 443–487, Pls. 14–33, Oosaka.

Explanation of the Plate XX

Fig. 1. *Neopercis multifasciata* (DÖDERLEIN) parasitized by *Phrixocephalus triangulus* WILSON. Cat. No. 736. ×0.95.

Fig. 2. Same. Cat. No. 10. ×4.8.

Fig. 3. *Cepola schlegeri* BLEEKER parasitized by *Phrixocephalus cepolae* YAMAGUTI. ×1.2.

Fig. 4. *Callionymus richardsoni* BLEEKER parasitized by *Phrixocephalus umbellatus* n. sp. Cat. No. 318. ×1.5.

Fig. 5. *Branchiostegus auratus* (KISHINOUYE) parasitized by *Phrixocephalus vipereus* n. sp. ×0.9.

Fig. 6. *Calliurichthys japonicus* (HOUTTUYN) parasitized by *Phrixocephalus reniformis* n. sp. ×1.0.

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Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 2, No. 2, September 30, 1956

Copepods Parasitic on Japanese Fishes

12. Family Lernaeopodidae

(*With 20 Text-figures*)

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The family Lernaeopodidae is widely distributed among fishes in both saline and fresh water. It is remarkable not only for the peculiar mode of its life, but also for striking degeneration in the structures of the body. It shows a distinct sexual dimorphism, the differences between the sexes manifesting themselves in an extreme inequality in size and in a corresponding dissimilarity in the structures of the body and the appendages.

The female is soft-bodied and strongly deformed, lacking, at the same time, any trace of distinct segmentation. She usually fastens herself to the gills of fishes, or to the wall of their buccal cavity, but in certain cases she adheres elsewhere, for example, to the body surface. Organ of adhesion used by her is the 1st maxillipeds which are transformed into fleshy arms. They are sometimes short, sometimes long. When short, they are highly flexible and usually separated to their tips, where they are united to the peduncle of the bulla. If they are short, they are fused together, in most cases, for their entire length. The bulla is composed of the hardened secretion from the frontal gland and is entirely enveloped by the tumor of the host tissue, the formation of which has been caused by irritation due to further secretion. Such an organ of fixation is peculiar to the present family and nothing like this is found in any of other parasitic copepods. Another important modification found in the 1st maxillipeds is their displacement toward the rear of the body, which occurs during the course of ontogeny. This is the case in the subfamily Clavellinae, where they are removed for a considerable distance behind the 2nd maxillipeds, so that the sequence of appendages is inverted. The 2nd maxillipeds, which are ordinarily the powerful organs for fixing the body to the host skin in the other families, have lost this function. Although they are chelate as in others, they are much reduced in size and are used only temporarily for holding the host skin while the parasite takes its food. In the subfamilies Lernaeopodinae and Clavellinae, both of which are treated in this report, they are placed close to the mouth tube.

The arms and the chelate limbs were termed by WILSON (1915) the 2nd maxillae and the maxillipeds. HEEGAARD (1947), however, from the results of his comparative studies on the copepod appendages, reached the conclusion that

these correspond to the 1st and 2nd maxillipeds. It is very strange that YAMAGUTI (1939), in his description of Japanese Lernaeopodidae, designated the 1st and 2nd maxillipeds as the 2nd and 1st, reversing the order.

The male is a dwarf and usually attaches to the female in the close vicinity of the genital aperture. He may, however, be found somewhere else on her body, e. g., cephalothorax, caudal processes etc. Both pairs of maxillipeds are very similar to each other and are definitely chelate, being used for prehension. Their relative position is never inverted in any of the subfamilies. It is a general rule that the male is less frequently discovered than the female, which, however, accompanies sometimes more than one male. In any lot of specimens obtained from a single individual of host, the male is usually much fewer than the female in number. Of the hitherto known species of this family, there are many which are represented only by the female.

Although a number of species belonging to this family have been recorded from out waters, the present collection adds 9 more species, 6 of which are new to science, the rest being new to Japan. It comprises, further, 4 species already known to occur in Japan, 2 of these being accompanied with the male which has been unrecorded. The following contains the full description of these 13 species. The type specimens will be preserved in the Prefectural University of Mie.

Family Lernaeopodidae MILNE-EDWARDS
Subfamily Lernaeopodinae WILSON
Genus *Lernaeopoda* BLAINVILLE, 1822
Lernaeopoda longicaudata HANSEN, 1923

(Figs. 1–3)

HANSEN 1923, pp. 54–56, Pl. 4, Figs. 2, a–o.

Occurrence: 11 females and 1 male, on the body surface of *Centrophorus acus* GARMAN, at Tanabe, Wakayama Pref., June 24, 1944; 5 females, on *C. atromarginatus* GARMAN, at Kannoura, Kôti Pref., June 27, 1944; both lots were collected by Prof. Y. Okada.

Distribution and hosts: Atlantic Ocean (South of Iceland, South-west of Faeros), on *Centrophorus squamosus*, on pectoral fin (HANSEN[23]).

Female: Total length exclusive of posterior processes 0.87, length of posterior processes 0.85, width of trunk 0.31, length of 1st maxillipeds (extended) 2.81, of egg tube 1.24 (all in mm.); cephalothorax and arms yellowish white in preservative, trunk whitish, and egg strings yellowish to pale yellowish brown.

Cephalothorax in line with trunk, or slightly flexed dorsally, short, less than half as long as trunk, and covered with a distinct, ovate, convex carapace, which occupies more than half of cephalothoracic length. It is circumscribed

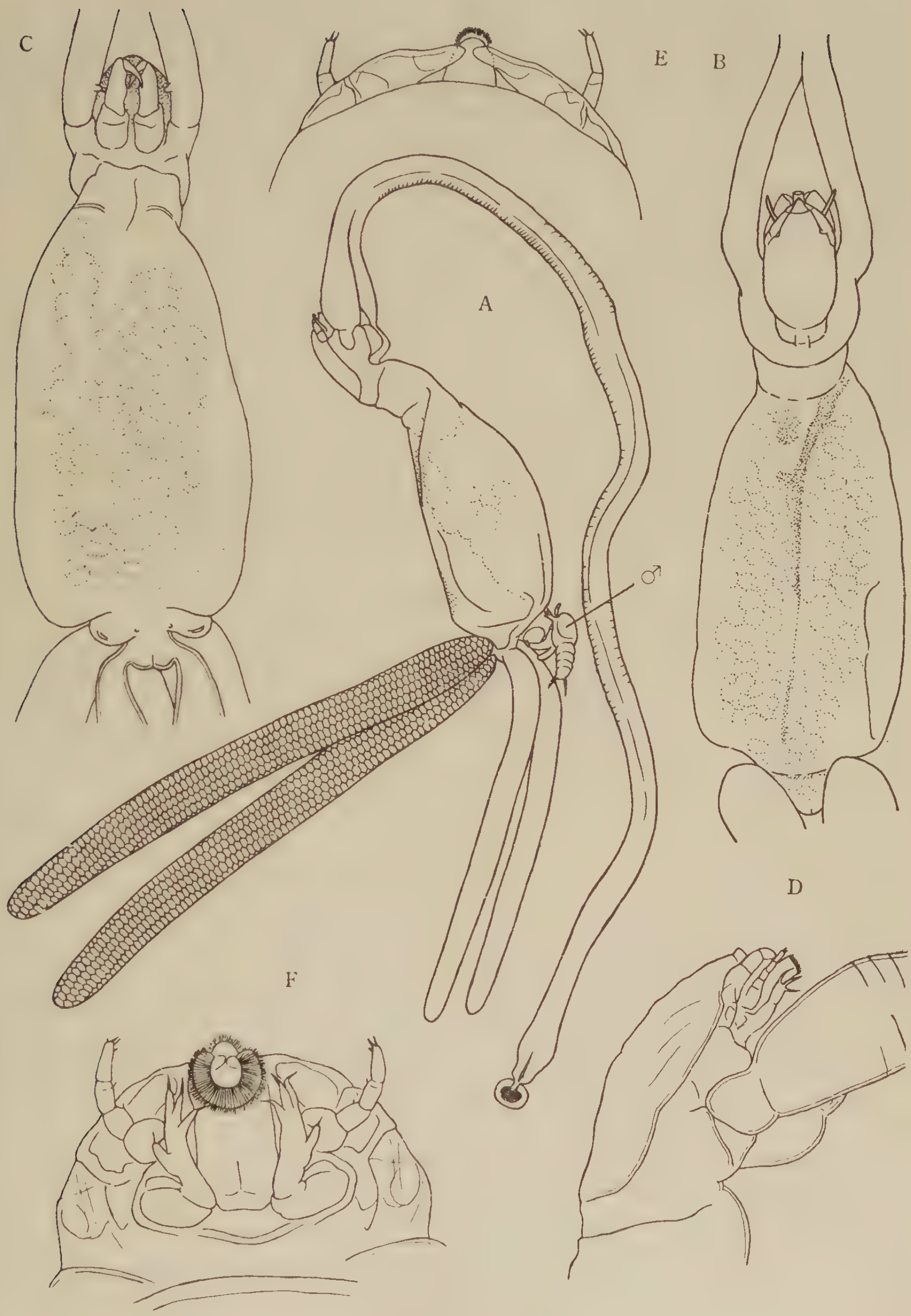

Fig. 1. *Lernaeopoda longicaudata* HANSEN, female. A, female carrying male, lateral aspect; B, dorsal aspect; C, ventral aspect; D, cephalothorax, lateral aspect; E, front end of carapace, dorsal aspect; F, cephalic region, ventral aspect, with 2nd maxillipeds removed. A ×6.2, B, C ×9.3, D ×19, E, F ×41.

by a more or less distinct ring of groove a short distance behind carapace. Trunk elongate, about half as long as wide, gradually narrowing forward and demarcated from cephalothorax by similar groove; postero-lateral angles round. Posterior border bears a pair of genital processes in the form of oval bulges and projects between these and on either side of midline a pair of long processes. These latter extend backward for about the length of body and are slenderer and shorter than egg tubes which are dorsal to them.

First antennae long, 4-jointed. Basal joint swollen like a round knob and making a right angle with filiform succeeding joints; 2nd and 3rd joints with a short subterminal spine and 4th tipped with a bunch of few spines. Second antennae turned inward, with relatively slender, indistinctly jointed basipod which is surmounted with unjointed exopod and 2-jointed endopod. Exopod truncate and granulose at apex, and with 2 minute spines widely apart from each other. Apical joint of endopod with 2 dorsal and 1 ventral spines, most dorsal one of these stouter than other 2 which are subequal. Labrum triangular, labium semicylindrical, both fringed with hairy marginal lamella. Mandibles have 3 principal teeth, each followed by an intermediate one, and 4 secondary ones behind them. Maxillae slender, curved like L, tipped with 3 sharp, equal-sized spines; palp small, composed of crescent base and short rod, ending in 3 tiny spines. First maxillipeds just outside 2nd maxillipeds, protruding forward, and strongly elongate, attaining more than thrice the length of body; members of both sides fused together except in a short basal portion, and provided with a small papilla on inner side close to the base. Bulla a circular disc. Second maxillipeds 3-jointed, with apical 2 joints forming a chela. Palm of the chela relatively narrow; its inner border raised into finely spinulose longitudinal ridge which is interrupted by a central notch, and bearing a short spine at the bottom of this notch. Claw reaching the base of palm, reinforced by a sharp terminal spine, which is associated with 2 short basal spines, and furnished with another short one near the base of claw; inner border spinulose behind terminal spine.

Male: Length exclusive of caudal rami 2.10 mm., carapace 0.61 mm. wide; pale yellowish in preservative. Only slightly bent ventrally, having well-developed trunk.

Cephalothorax with carapace distinct, strongly convex, and oblong ovate in dorsal aspect; ventral side also swollen. Trunk cylindrical, as long as cephalothorax, uniform in width, and divided by transverse grooves into 4 subequal segments and much smaller abdomen.

Antennae and proboscis protruding forward. First antennae filiform, 5-jointed, terminal joint tipped by a few spines, and antepenultimate joint with a single inner one. Second antennae have protopodite composed of 2 joints, 2nd of which is much the longer. Exopod indistinctly bordered at base, round at apex

Fig. 2. *Lernaeopoda longicaudata* HANSEN, female. A, 1st antenna; B, 2nd antenna; C, apical portion of same, ventral view; D, same, inner view; E, same, outer view; F, labrum, inner face; G, labium, outer face; H, mandible; I, maxilla; J, basal tubercle of 1st maxilliped; K, 2nd maxilliped; L, same, with claw and inner border of palm enlarged. A, I, J ×120, B, F, G, L ×80, C–E, H ×170, K ×40.

and with 2 spines widely apart. Endopod 2-jointed, with 1st joint as long as exopod, and 2nd joint short, carrying 3 spines on distal margin, most dorsal one of these being well curved and far stouter than others. Maxillae trilobed, each lobe ending in an acuminate spine; palp rod-shaped, with 2 spines. First maxillipeds of good size; palm strongly swollen, transversely oval, with inner margin forming a bulge which accompanies 2 round, secondary tubercles, armed with minute spinules; claw strongly built, but with tip mutilated. Second maxillipeds feebler than preceding chelae having much narrower palm. Palm oblong, twice as long as wide, produced at inner distal anlge into a pointed conical

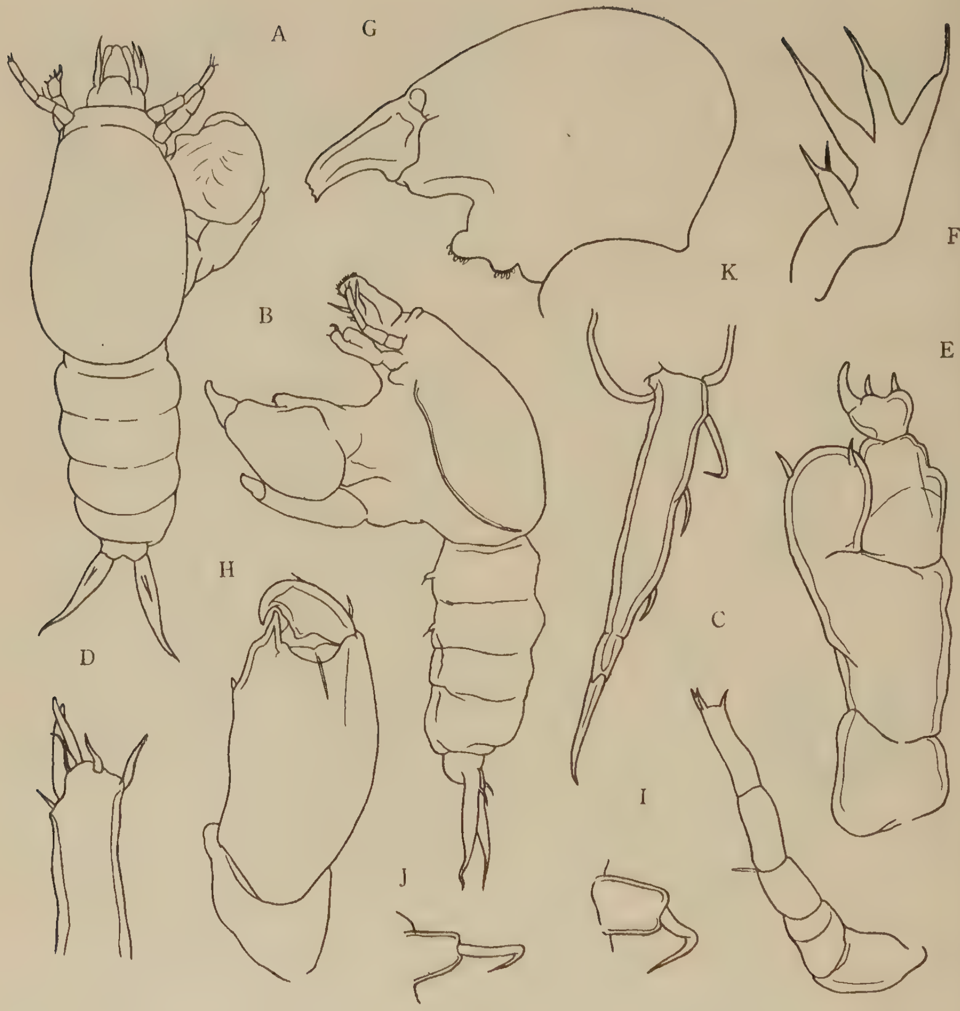

Fig. 3. *Lernaeopoda longicaudata* HANSEN, male. A, dorsal aspect; B, lateral aspect; C, 1st antenna; D, tip of same; E, 2nd antenna; F, maxilla; G, 1st maxilliped; H, 2nd maxilliped; I, 1st leg rudiment; J, 2nd leg rudiment; K, caudal ramus. A, B ×34, C, K ×120, D, I, J ×340, E ×200, F ×170, G, H ×80.

process and with a tiny spine somewhat behind. Claw stout but short, strongly curved, carrying a feeble spine at base, and shutting down past the named process of palm. First 2 trunk segments furnished each with a pair of papilliform limb rudiments which are tipped with a single hair. Following segments limbless. Caudal rami elongate, filiform, carrying 3 spines on dorsal border, besides a stronger terminal one.

Remarks: The present specimens are in strict accord with those described by HANSEN[23] in every detail of both sexes. It is very interesting that the species known from the North Atlantic alone was obtained from the Pacific. The species

appears to be distributed among the sharks of the genus *Centrophorus* as this may be perceived from the record inserted above. It resembles in its appearance *Lernaeopodina longibrachia* (BRIAN)[11,12], especially in the possession of elongate arms and 2 long caudal processes, but is quite different in that these processes are ventral to the egg sacs instead of dorsal as in BRIAN's species. Moreover, the 2 arms are united for a far longer distance in HANSEN's species.

Lernaeopoda etmopteri YAMAGUTI, 1939

(Figs. 4 & 5)

YAMAGUTI 1939, pp. 549–550, Pl. 44, Figs. 104–106, Pl. 45, Figs. 107–109.

This species has been known only from the female. The present material comprises a single specimen of the male.

Occurrence: 3 females and 1 male, on *Etmopterus lucifer* J. & S., attaching to dorsal side of body just behind each of anterior and posterior dorsal fins, off Owase, Mie Pref., by Mr. K. SUZUKI.

Female: Length as the body flexed 3.74, width at posterior end 2.60, length of egg tube 4.07 (all in mm.); yellowish white in alcohol.

Cephalothorax bent ventrally; carapace more or less distinct, triangular, narrowing forward, and with slight lateral depressions just behind round front. Neck short, half as long as and narrower than carapace, a trifle widening backward, and more or less corrugated. Trunk triangular, slightly shorter than wide, with caudo-lateral angles swollen in round lobes, and traversed by 3 inconspicuous ridges across mid-ventral surface. Caudal margin sinuate on the median, but with an inconspicuous, transverse lamella which bears a rudimentary, spiniform, apically curved process on each side. The process is associated with 2 short basal spines. Egg tubes about as long as body.

First antennae short, 4-jointed; 2nd joint with a single spine close to base, 3rd with a vestigial subterminal one and 4th with an apical bundle of hairs. Second antennae with exopodite much broader than and extending beyond endopodite. Free margin of exopodite widely round, and cut into inconspicuous lobes, which are covered with file-like area; it is provided, further, with a circular subterminal papilla tipped by a very short spine on inner surface. Endopodite 2-jointed, basal joint carrying a round boss with file-like surface on ventral border, and apical joint bearing a similar crescent ventral boss and 3 apical spines, dorsalmost of these being far longer than others. Mandibles have 5 principal teeth followed by 2 slender secondary ones; a minute intermediate tooth is inserted between every adjoining 2 of principal teeth. Maxillae slender, in the shape of L, tipped with 3 flattened, but sharply pointed spines; palp rod-like, with same number of minute spines. First maxillipeds relatively short, placed outside and just behind 2nd maxillipeds, projecting ventrally; members of

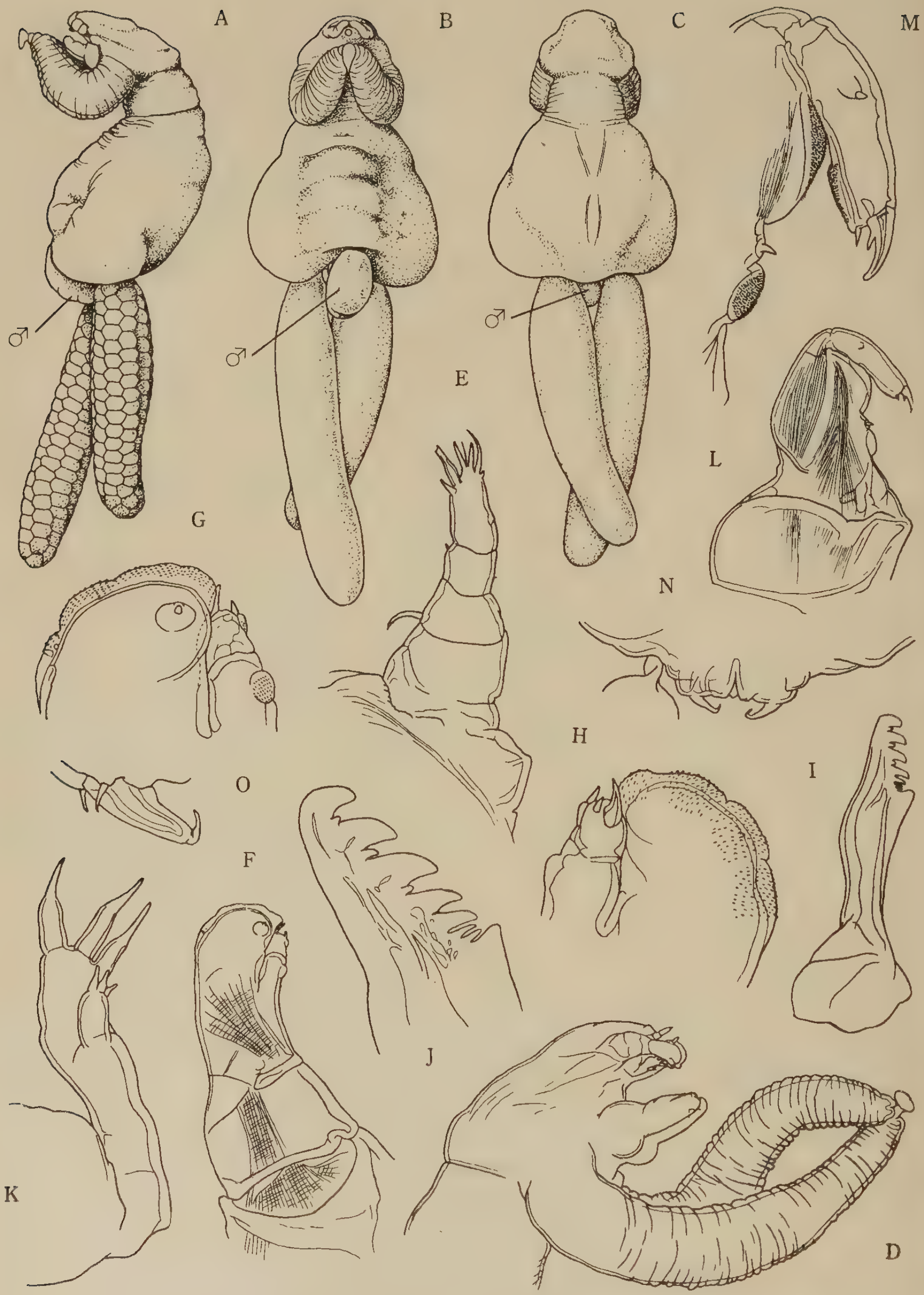

Fig. 4. *Lernaeopoda etmopteri* YAMAGUTI, female. A, female carrying male, lateral aspect; B, ventral aspect; C, dorsal aspect; D, cephalothorax, lateral aspect; E, 1st antenna; G, tip of same, outer face; H, same, inner face; I, mandible; J, tip of same; K, maxilla; L, 2nd maxilliped; M, same, claw and inner border of palm; N, caudal end of trunk; O, caudal process. A–C ×10, D ×19, E, I, K ×170, F ×85, G, H ×200, J, O ×490, L ×52, M ×120, N ×27.

Fig. 5. *Lernaeopoda etmopteri* YAMAGUTI, male. A, dorsal aspect; B, ventral aspect; C, lateral aspect; D, 1st antenna; E, tip of same; F, 2 rami of 2nd antenna; G, maxilla; H, 1st maxilliped; I, 2nd maxilliped; J, 1st leg rudiment; K, 2nd leg rudiment; L, caudal ramus. A–C ×27, D ×170, E ×490, F, J, K ×330, G ×180, H, I ×120, L ×135.

both sides separated to the tip and encircled by a series of wrinkles along their entire length. Bulla a button-shape. Second maxillipeds with basal joint swollen, widening transversely. Palm slender, provided with a minute spine at about the center of inner border, and with 2 narrow densely spinulose area, one proximally and the other a short distance distally to that spine. Claw stout, but not strongly curved, tipped by a stronger outer spine, bearing a short accessory branch, and a feebler, simple inner spine; inner border ridged and finely spinulose for some distance backward from apex; outer surface of claw furnished with short spine behind the center.

Male: Body large in relation to the size of female, strongly bent ventrally in V-shape, but ovoid in dorsal aspect, 1.74 mm. long as body flexed, 1.00 mm. wide; similar to female in color.

Cephalothorax with carapace inconspicuous, swollen dorsally, depressed ventrally, and with anterior end narrowed, being cuneiform in lateral aspect, but

well round in dorsal aspect. Trunk indistinctly differentiated from cephalothorax, with which it makes a rectangle and to which it is equal in length. It decreases in width and thickness backward and lacks segmentation. Abdomen small, mammiform, more or less distinct from preceding region.

Cephalic appendages and proboscis projecting ventrally. First antennae 4-jointed; 1st joint with a spine and 4th with a large-sized, subterminal sensory lamina besides with ordinary terminal laminae and spines. Exopod of 2nd antennae broader than endopod, round on free margin and carrying 2 short submarginal spines, one close to dorsal and the other to ventral angles. Endopod 2-jointed, with both joints thickly spinulose on a narrow area along posterior border; apical spines 3 in number, disposed 1 at posterior and 2 at anterior angles, anteriormost of these being far stouter than others and sharply curved. Maxillae slender, tripartite, each lobe ending in a sharp spine; palp rod-shaped, with 2 feebler spines. First maxillipeds powerful, with inflated, huge palm which is broader than long and nearly triangular; claw rather stout, with thick base and strongly curved, hook-like apex. Second maxillipeds also robust; palm swollen, transversely ovate, reinforced with a quadrate process at inner distal corner. Claw well-curved, very broad at base and rapidly attenuating toward apex which reaches beyond that process of palm; it has a short accessory spine near base. Mid-ventral surface in the region between 2 pairs of maxillipeds provided with a conical process. Trunk carries in its anterior region 2 pairs of limb rudiments which are short cylinders surmounted with a hair. Caudal rami lanceolate, acuminating, and armed with terminal spine as well as with 2 minute spinules on external border.

Remarks: The present species is distinguished from the other species of the genus above all by that the trunk processes are vestigial. In *L. globosa* Leigh-Sharpe[32] the processes are also much reduced, and yet far larger in size than in the present case. The reduction of the processes in *etmopteri* appears, at first sight, to be sufficient to reject it from *Lernaeopoda*, and strongly recalls the condition that is found in *Ommatokoita elongata* (Grant)[37, 51, 52, 56, 62] and in *O. superba* Leigh-Sharpe[37], where the processes are represented merely by 2 short knobs. The present species, however, differs from them in that it lives on the body surface of host but not on the eye as they do, in the stockier body and in the much shorter 1st maxillipeds. *Lernaeopodopsis productus* Hansen[23] is another species in which the processes are reduced and replaced by a pair of tubercles. As its genus name indicates, *productus* also has no intimate relation with the present species, for it has the 2-jointed 1st antennae, bifid maxillae and the 1st maxillipeds fused almost from the base. In spite of the rudimentary condition of the posterior processes, the most appropriate place to which the present species can be assigned is, without doubt, *Lernaeopoda*.

Lernaeopoda oviformis n. sp.

(Fig. 6)

Occurrence: A single female, no male, on the outside surface of *Squalus mitsukurii* JORDAN & FOWLER, at Kannoura, Kôti Pref., 200–400 m. deep, by Prof. Y. Okada, June 27, 1944.

As it was not desirable to mutilate the only specimen, the detailed study of the appendages was not made.

Female: Holotype. Length excluding posterior processes 4.13, width of trunk 2.66, length of posterior processes 2.60, of 1st maxillipeds 5.42, of egg tube 3.86 (all in mm.); color in alcohol yellowish, with yellowish brown egg strings.

Body stumpy, with cephalothorax short and strongly flexed ventrally. Carapace distinct, round in front, somewhat expanded backward and depressed dorsoventrally. Neck short, composed of 2 short ring-like segments, which are separated from each other as well as from carapace by deep groove; 1st segment narrower than carapace and 2nd wider and longer than 1st. Trunk oblong ovate, broad and thick, about one and a half times as long as cephalothorax, longer than wide, and more or less warty on dorsal side. It carries at caudal end and ventrally to egg tubes a pair of sausage-shaped processes which are slightly shorter than trunk and constricted at base. Caudal margin of trunk between the processes are produced in a pair of round tubercles adjoining together. Egg tubes longer and much broader than the processes, about as long as body, and 3 and half times as long as broad.

First antennae 4-jointed. Second antennae turned inward along frontal margin of carapace to overlap each other on the midline, bipartite; exopodite 2-jointed. Maxillae tripartite, accompanying palp. First maxillipeds with their base placed close behind 2nd antennae and just outside 2nd maxillipeds, projecting from carapace at right angles, and strongly elongate backward to reach caudal processes; members of 2 sides entirely separated to the tip, encircled by fine annulets along their entire length, covered with granules on outer surface of terminal half, and bearing an inner tubercle near base. Bulla a mushroom-shape. Second maxillipeds close to cephalic appendages, with sharp claw.

Remarks: Although the male is unknown to us, the character of female clearly tells that the species is referable to the genus *Lernaeopoda*. In the general appearance of body, namely in that the short cephalothorax is turned ventrally toward the plump trunk and projects the 1st maxillipeds backward to extend beyond the trunk, the present species resembles most closely to THOMSON's illustration on *L. musteli* THOMSON[58]. The two, however, are different in the length of the posterior processes, for these of *musteli* do not surpass even 1/6

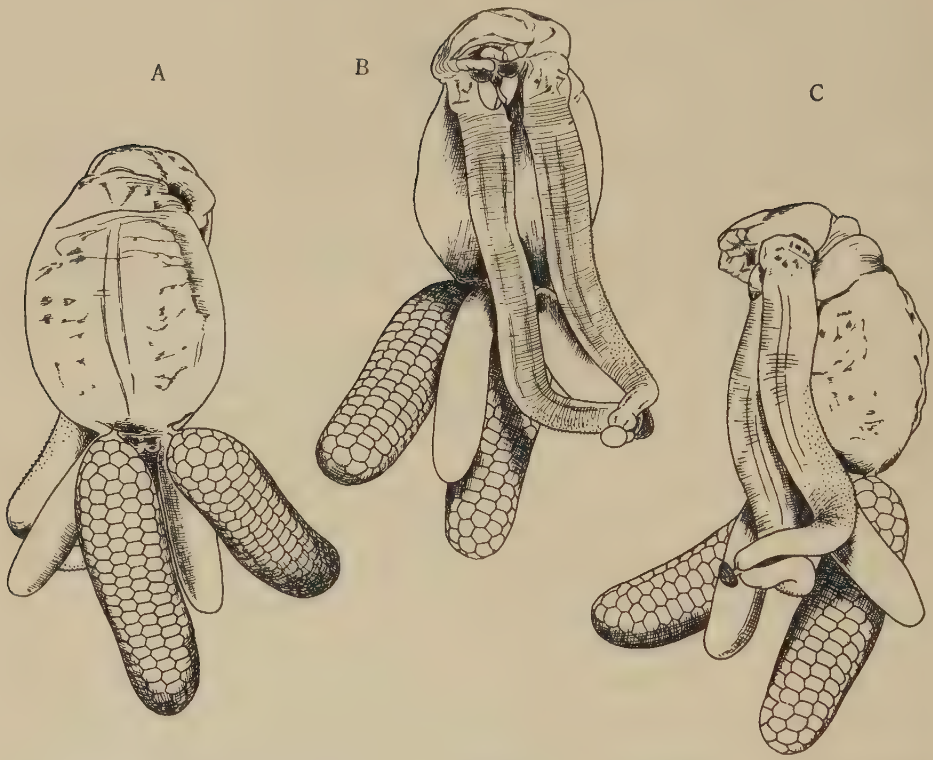

Fig. 6. *Lernaeopoda oviformis* n. sp., female. A, dorsal aspect; B, ventral aspect; C, lateral aspect. ×10.

of the trunk length. In having the elongate posterior processes, the new species is nearly allied to *elongata* HANSEN[23] and *scyllicola* LEIGH-SHARPE[30,31]. It differs from *elongata* in the 1st maxillipeds being much shorter and quite distinct from each other, and from *scyllicola* in the trunk being shorter and plumper. Difference from the other species of the genus may be found in the length of the named processes, which are only inconspicuous structures in greater part of them. *L. galei* (KRφYER)[52], *mustelicola* LEIGH-SHARPE[34], and *bidiscalis* KANE[52] are the species where the processes are relatively well-developed. Their processes are much shorter than those of the present species and their 1st maxillipeds also are relatively shorter.

Subfamily Clavellinae WILSON, 1915

Genus *Charopinus* KRÖYER, 1863

Charopinus markewitschi GUSSEV, 1951

(Fig. 7)

Гусев 1951, pp. 436–441, Figs. 28–29.

Occurrence: 9 females, on *Dasyatis ushiei* JORDAN and HUBBS, on the floor of buccal cavity, at Seto, Wakayama Pref., by myself, July 2, 1943. No male.

Distribution: U.S.S.R. (Khanton Bay, Antonovo Bay) *Raja kenojei*

[Gussev], Japan (present record).

Female: Cephalothorax whitish, trunk pale yellowish brown and egg strings pale yellowish to yellowish brown in preservative; length from front to the base of 1st maxillipeds 2.84, same from the latter to caudal end 4.78, width of trunk 1.83, length of 1st maxillipeds, extended 2.78, of egg tube 4.39 (all in mm.).

Cephalothorax moderately long, strongly flexed backward at the base of 1st maxillipeds, making a V-shape with trunk. Carapace distinct, occupying anterior half of flexed region and slightly turned toward opposite direction. It is longer than wide, convex on dorsal side, depressed on ventral side, and has widely round frontal margin. Region posterior to 1st maxillipeds short, almost in line with trunk, indistinctly separated from it, and more or less rugose on surface. Trunk elongate, twice as long as wide, gradually but insensibly narrowing forward, somewhat depressed dorsoventrally, and with angular postero-lateral corners. Posterior margin produced on the median into a quadrate lobe carrying a pair of pointed, foliaceous laminae, which terminate in a tiny spinule and bear similar 2 on external margin.

First antennae 2-jointed, basal joint broad, with 1 subterminal spine, and apical joint narrow, cylindrical, ending in a few spines. Second antennae turning inward, but not meeting on the median, with protopodite distinctly jointed and bearing 2 rami indistinctly bordered at their bases. Endopodite unjointed, triangular, furnished on outer surface with an oval accessory lamina which is margined by fine granules. Exopodite linguiform, provided on outer surface with a short blunt papilla besides with marginal granules, and bearing on inner surface along entire dorsal margin fine striae which stand at right angles to the margin. Proboscis projecting antero-ventrally. Mandibles armed with 4 principal and 3 secondary teeth, every consecutive 2 of former series interposing a tiny intermediate one. Maxillae slender, tipped by 3 sharp spines; palp small in size, ending in 2 shorter spines. First maxillipeds removed for a considerable distance behind 2nd maxillipeds and projecting in a direction opposite to that of carapace. They are about as long as cephalothorax and separated to the tip where they are united together, forming 2 semicircular, closely adjoining discs which hold button-shaped bulla between each other. They bear a series of annular rugae on their surface. Second maxillipeds placed close to cephalic appendages. Palm slender, more than twice longer than wide, with sides nearly parallel; inner border carrying a short, low, granulated ridge at distal end and a conical protuberance tipped by sharp spine a short distance behind. Claw stout, reaching the center of palm, granulose on a narrow terminal area along inner border and carrying a short spine behind the center; terminal spine strong, sharply pointed, bearing a minute inner branch and associated at

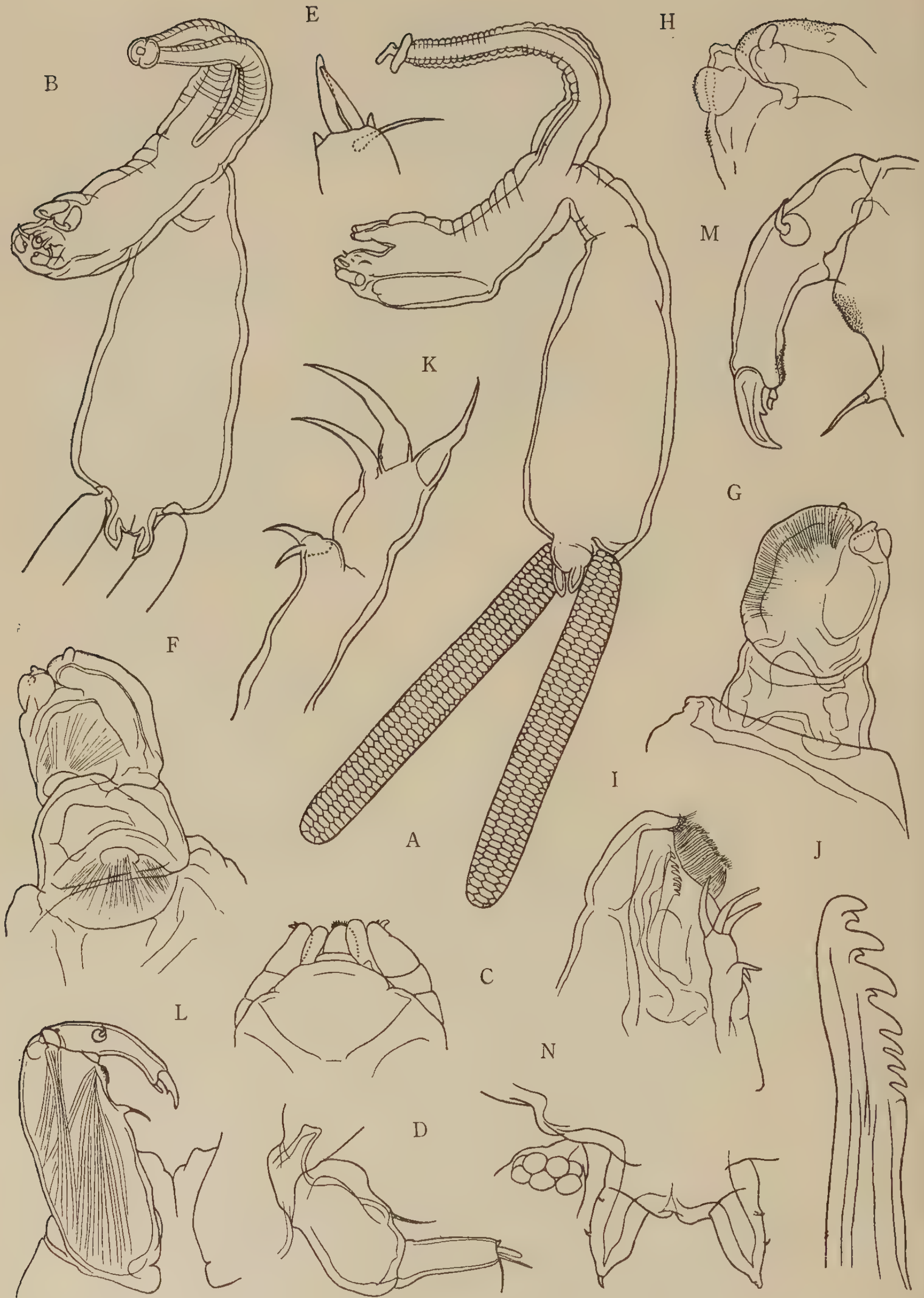

Fig. 7. *Charopinus markewitschi* GUSSEV, female. A, lateral view; B, dorsal view; C, frontal end of carapace, dorsal view; D, 1st antenna; E, tip of same; F, 2nd antenna, outer face; G, same, inner face; H, tip of same, outer face; I, proboscis and maxilla, lateral view; J, mandible; K, maxilla; L, 2nd maxilliped; M, same, claw and inner border of palm; N, caudal end of trunk. A, B ×12, C, N ×41, D, F, G, I ×120, E, K ×340, H, M ×170, J ×490, L ×85.

the base with a short accessory spine. Egg strings columnar, relatively slender, and slightly longer than trunk.

Remarks: This is the first record of the species from Japan. The specimens found on the new host from our waters are in strict accord with those described by GUSSEV[22] from *Raja kenojei* under the name of *C. markewitschi*. This species bears a close resemblance to *C. pastinacae* VAN BENEDEN[4, 14] in having the foliaceous processes at the caudal end of trunk. These, however, are much more rudimentary in the present case.

Genus *Brachiella* CUVIER, 1817

Brachiella thynni CUVIER, 1817

(Figs. 8 & 9)

Brachiella thynni, CUVIER 1817, Règne Animal, p. 287, Pl. 15, Fig. 5 (after BRIAN); MILNE-EDWARDS 1840, p. 512; STEENSTRUP & LÜTKEN 1861, pp. 420–422, Pl. 15, Fig. 36; HELLER 1866, p. 34; VOGT 1877, p. 426, Pl. 3. Fig. 9; BASSETT-SMITH 1896b, p. 162; 1899, p. 502; GRAEFFE 1902, p. 16; STENTA 1904, pp. 345–347; MICULICICH 1905a, pp. 599–620; BRIAN 1906, pp. 105–106, Pl. 9, Fig. 1; SCOTT, T. & A. 1913, pp. 204–205, Pl. 64, Figs. 4–6; WILSON 1915, pp. 703–705, Pl. 25, Fig. C, Pl. 53, Figs. 209–215; LEIGH-SHARPE 1926, p. 346; KIRTISINGHE 1935, p. 342, Figs. 40–41; BERE 1936, p. 613; CAUSEY 1953, p. 15; DELAMARE-DEBOUTTEVILLE & NUNES-RUIVO 1954, p. 217.

Thynnicola ziegleri, MICULICICH 1904, pp. 47–52, Figs. 1–3. (As regards further bibliography see BRIAN 1906)

Occurrence: 17 females, 5 of these accompanying each a male, on *Acanthocybium, solandri* (C. & V.), off Owase, Mie Pref., by myself, November 18, 1953. Female attaches in the axil behind pectoral fin, or on hind surface of, or close to the base of that fin; male clings to posterior process of female in most cases.

Distribution: Ådriatic (HELLER[27], MICULICICH[13], WILSON[62], GRAEFFE[20]), Miditerranean (BRIAN[10], DELAMARE-DEBOUTTEVILLE & NUNES-RUIVO[18]), Belgian coast (VAN BENEDEN), British coast (BASSETT-SMITH[2], WILSON[62], LEIGH-SHARPE[38], SCOTT, T. & A.[52]), Gulf of Mexio (BERE[6], CAUSEY[16]), Ceylon (KIRTISINGHE[28]), Western Pacific (present record).

Host: *Thynnus thynnus*, on gills [GRAEFFE[20], WILSON[62]], on pectoral fin or its axil [BASSETT-SMITH[2], MICULICICH[43], LEIGH-SHARPE[38]], *Orcynus thynnus*, on gills [SCOTT, T. & A.[51]], *Scianea aquila* [BASSETT-SMITH[3]], *S. umba* [VAN BENEDEN], *Scomberomorus cavalla* [CAUSEY[16]], *Pomatomus saltatrix* [BERE[6]], *Thunnus (Germo) macropterus* [KIRTISINGHE[28]], *Acanthocybium solandri* (present record), on pectoral fin or just behind it in all of these latter cases.

BASSETT-SMITH (1899) was the first in recording the species from the pectoral fin of host. MICULICICH (1904) definitely stated later that "Bei meinen

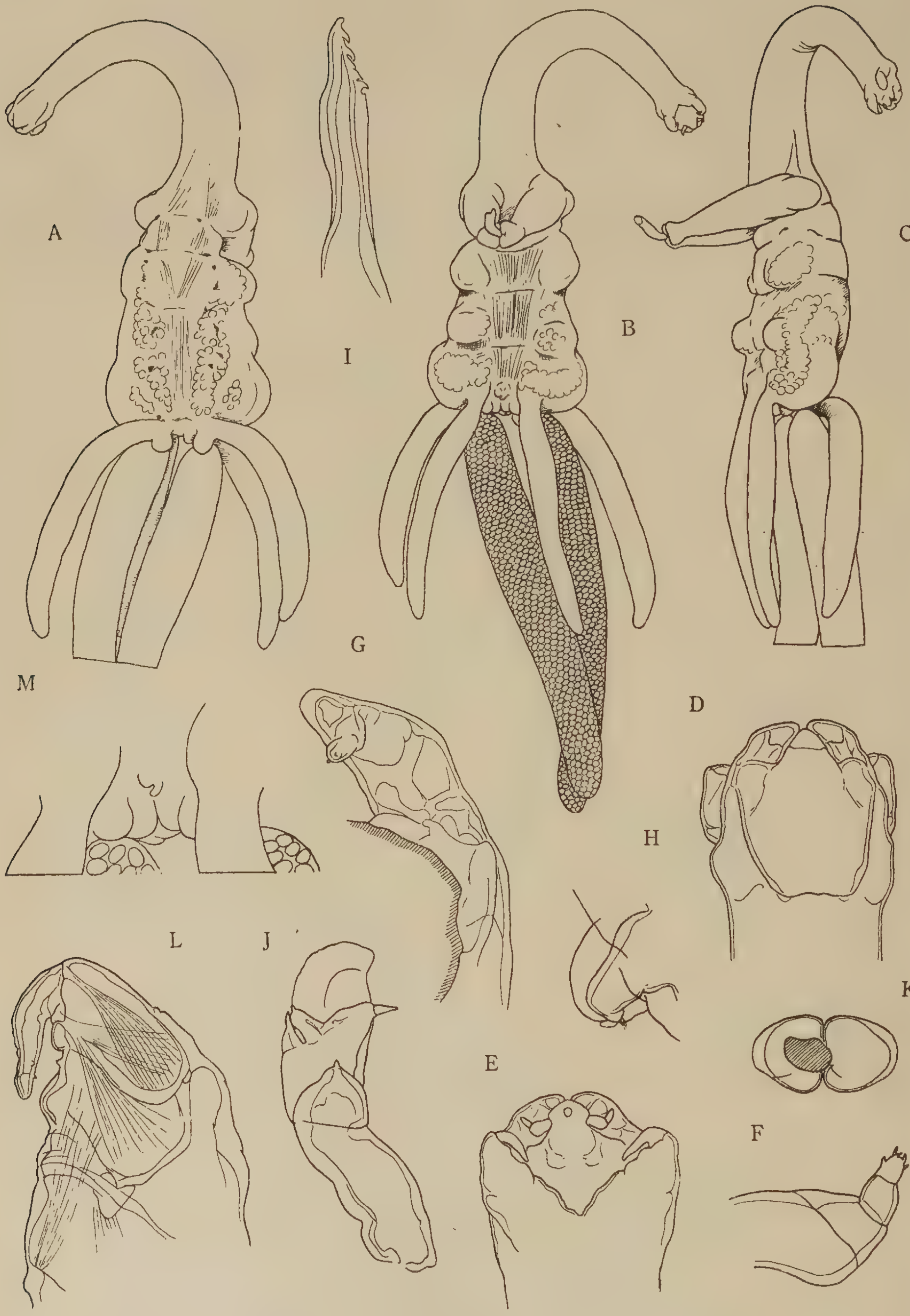

Fig. 8. *Brachiella thynni* Cuvier, female. A, dorsal view; B, ventral view; C, lateral view; D, carapace, dorsal view; E, same, ventral view; F, 1st antenna; G, 2nd antenna; H, endopod of same; I, mandible; J, maxilla; K, tip of 1st maxillipeds; L, 2nd maxilliped; M, caudal end of trunk, ventral view. A–C ×6.3, D, E ×27, F ×170, G, L ×85, H, J ×340, I ×490, K, M ×19.

Beobachtungen an über hundert Fischen fand ich, *B. thynni* nie an den Kiemen des Thunfisches, sondern immer hinder der Brustflosse in der Bucht, welche die Flosse mit dem Körper bildet." Since then, most authors do not recognize the infection on the gills, this appearing, without doubt, merely accidental.

Female: Measurements of largest female: total length 42.00; cephalothorax 12.53 long, trunk 6.35 long, 4.09 wide, 2.96 thick, 1st maxilliped 2.11 long, ventro-caudal process 9.30 long, dorso-caudal process 8.58 long, egg string 21.8 long (all in mm.). Color whitish, genital segment tinged with pale pinkish color, and egg strings pale pinkish to brownish.

Cephalothorax strongly elongate and flexible, cylindrical, slightly growing wider backward, and abruptly expanded at hind end where 1st maxillipeds are projecting. Fore end somewhat widened and covered by very small, but well-defined carapace; front of carapace produced on the median into a triangular lobe, but truncate on either side of it; lateral sides converging backward to join with almost straight hind border. Trunk distinct from and shorter than cephalothorax, about 1/3 longer than wide, and wider posteriorly than anteriorly. Three segments are defined dorsally, and 4 ventrally, owing to the development of somewhat inconspicuous surface grooves as well as of indentations of lateral sides. Dorsal surface smooth and convex; ventral surface flattened, but raised on either side in 2 pairs of round bosses, 1 pair on each of 2nd and 3rd segments. Caudal end carries 2 pairs of lanceolate processes, disposed one dorsally to egg tubes and the other ventrally. They are subequal in size, close to midline, and extend backward for a length surpassing trunk. Dorsal processes protrude laterally at their origin where they bear an oval lobe, then curving, direct backward. Posterior border of trunk tubercular in median region between those processes. Egg tubes extending far beyond the processes.

First antennae 3-jointed; basal joint broad, divided into 2 subjoints by a faint line, other joints much shorter and narrower, and tipped with a few tiny spinules. Second antennae turned inward along the sides of median lobe of carapace, with blunt, unarmed apex and bearing behind it a short claviform rudiment of endopod which is tipped with a few papillae. Mandibles pointed at apex and marginated with 5 recurved teeth. Maxillae trilobed, inner lobe directed inward, whereas other 2 outward and closely adjoining, all tipped by short spine; palp triangular, with 1 vestigial spine. Maxillae accompany, further, a linguiform accessory lamella which extends far beyond principal lobes. First maxillipeds protruding from lateral sides of cephalothorax at its posterior end, relatively short, separate to the tip which is semicircular disc. Bulla cylindrical. Second maxillipeds feeble, placed close to cephalic appendages, and widely apart from each other. Palm triangular, its inner border furnished with a distal quadrate and a proximal triangular pads which interpose a rudimentary spine.

Fig. 9. *Brachiella thynni* CUVIER, male. A, dorsal view; B, lateral view; C, 1st antenna; D, 2nd antenna; E, proboscis and maxilla; F, 1st maxilliped; G, 2nd maxilliped; H, caudal end. A, B ×135, C, D ×340, E ×600, F–H ×120.

Claw feeble, blunt at the tip, behind which it bears 2 papillae.

Male: Length exclusive of caudal rami 4.60, carapace exclusive of proboscis 2.40×1.25, trunk 2.31×1.08 (all in mm.); whitish in color, with a few scattered pigment patterns.

Cephalothorax distinct from trunk, covered dorsally by oblong carapace, which is twice as long as wide, truncate in front, round behind and has nearly parallel sides; ventral side swollen. Trunk fusiform, contracted at fore end into a narrow waist to join with the hind end of ventral face of cephalothorax, and abruptly expanded just behind, then tapering again backward. It is composed of 5 indistinct segments, 1st of which alone has distinct border on all sides; segmentation of all others is indicated only on ventral side by faint lines. Caudal end furnished with a pair of short quadrate processes ventrally and with longer fusiform caudal rami dorsally.

Cephalic appendages and proboscis projecting forward. First antennae 4-jointed; basal joint broad, with an unguiform stout spine, and succeeding joints columnar, tipped with 3 short spines. Second antennae biramous. Exopod a

slender lobe with round apex, unarmed; endopod extending beyond exopod, 2-jointed, and surmounted with 3 spinules. Maxillae narrowed at base, expanded at end and with 3 spines; palp slender, ending in a single spine. First maxillipeds with palm ovate, and claw strongly curved, ending in backward reflected tip. Second maxillipeds stouter than preceding limbs and extending much beyond these; basal joint swollen on outer side. Palm elongate, about thrice as long as wide, with nearly parallel borders; inner border furnished with 2 crescentic, tuberculated bulges and a round, unarmed basal bulge. Claw only slightly curved, reaching about the center of palm, tuberculated on its distal half and terminating in short, curved, unguiform spine. Trunk without limb rudiment.

Remarks: This is the first occurrence of this species from the Pacific Ocean. The specimens are in accord with the Atlantic ones in every essential point.

Genus *Clavella* OKEN, 1815

Clavella uncinata (O. F. MÜLLER), 1776

(Figs. 10 & 11)

Lernaea uncinata, MÜLLER 1776, Zoologiae Danicae Prodromus, Hafniae, p. 38, Pl. 33, Fig. 2 (after BRIAN).

Schisturus uncinatus, OKEN 1815, p. 183 (after BRIAN).

Clavella uncinata, OKEN 1815, p. 353; POCHE 1902 (after BRIAN); BRIAN 1906, pp. 110–111; 1912, pp. 40–42, Pl. 11, Figs. 7–8; GUIART 1913, p. 9; SCOTT, T. & A. 1913, pp. 214–215; Pl. 65, Figs. 2, 3 & 6, Pl. 66, Figs. 21–23; WILSON 1915, pp. 680–684, Pl. 27, Fig. M, Pl. 48, Figs. 167–173, Pl. 49, Figs. 174–176; 1922, p. 5; 1923, p. 14; 1932, pp. 513–514, Fig. 302; HANSEN 1923, pp. 59–61, Pl. 4, Fig. 4, a–l; LEIGH-SHARPE 1925, p. 195; SCOTT, A. 1928, p. 115; BERE 1930, p. 427; POULSEN 1939, pp. 223–244, Figs. 1–8; YAMAGUTI 1939, pp. 553–554; SPROSTON & HARTLEY 1941, pp. 380–386; STEPHENSEN 1943, pp. 14–15; HEEGAARD 1945, p. 25; 1947, pp. 134–154, Pls. 12–14, Figs. 89–110; GUSSEV 1951, pp. 445–449, Figs. 32–33.

Lernaeomyzon uncinatum, BLAINVILLE 1822, p. 438 (after BRIAN).

Anchorella uncinata, NORDMANN 1832, p. 102, Pl. 8, Figs. 8–12, Pl. 10, Figs. 1–5 (after BRIAN); M.-EDWARDS 1840, pp. 519–520; HELLER 1866, p. 35; OLSSON 1869, p. 45; VOGT 1877, p. 60, Pl. 4, Figs. 2–7; THOMPSON 1893, p. 39, Pl. 27, Fig. 2; BRIAN 1905, p. 8, Pl. 4, Fig. 8.

Anchorella agilis KRØYER 1863, pp. 374, 384, Pl. 16, Fig. 2, a–b (after BRIAN).

Anchorella lagenula, CUVIER 1817 (after VAN BENEDEN).

Clavella sciatherica, LEIGH-SHARPE 1918c, pp. 118–126, Figs. 1–8; 1920, pp. 334–338, Figs. 1, 2, 4–9; 1925, p. 195, Fig. 1B.

Clavella iadda, LEIGH-SHARPE 1920, pp. 332–338, Fig. 3; 1925, p. 196, Fig. 1D.

Clavella devastatrix, LEIGH-SHARPE 1925, p. 197, Figs. 2–3; 1926, p. 386, Fig. 1.

Clavella invicta, LEIGH-SHARPE 1925, p. 197, Fig. 4.

Clavella typica, LEIGH-SHARPE 1933, p. 117, Fig. 5.

Clavella deliciosa, LEIGH-SHARPE 1933, p. 117, Figs. 4–5.

(As to further bibliography see BRIAN 1906 and HANSEN 1923)

Occurrence: 17 females and 5 males, on *Gadus macrocephalus* (Tilesius), off Wakkanai, Hokkaidô, by Dr. K. Kuronuma, May 13, 1943. Two of the females were associated each with 2 males, these attaching to the genital processes or elsewhere.

Distribution: Danish coast (Müller, Krøyer, Poulsen[48]), Belgian coast (van Beneden), British coast (T. & A. Scott[52], Thompson[57], Bassett-Smith[2], Sproston & Hartley[53]), Irish seas (A. Scott[49]), Denmark (Krøyer), Norway (Olsson[47]), Iceland (Hansen[23]), Roscoff (Vogt[59]), Mediterranean (Brian[10]), Adriatic (Heller[27]), West Greenland (Heegaard[25]), Atlantic coast of N. America as far south as Massachusetts (Wilson[62,66]), Khanton Bay, Muravevo Bay & Komandorskiye Is. (Gussev[22]), Alasca (Wilson[62]), Bering Is. (Wilson[62]), Pacific coast of Canada (Bere[5]), West coast of S. America (Wilson[64]).

Hosts: *Gadus merlangus* [T. & A. Scott[52], Leigh-Sharpe[36], Sproston & Hartley[53], Bassett-Smith[2], etc.], *G. saida* [Stephensen[56], Heegaard[25]], *G. callarias* [Poulsen[48]], *G. ogac* [Hansen[28]], *G. aeglefinus* [Hansen[23] Olsson[47]], *G. morrhua* [Brian[10], Wilson[62]], *G. barbatus* [Brian[10]], *G. virens* [Olsson[47]], *G. pollachius* [Leigh-Sharpe[36], Sproston & Hartley[53]], *G. macrocephalus* [Wilson[60,62], Bere[6], Gussev[22]], *G. polaris* [Wilson[63]], *G. luscus* [Leigh-Sharpe[41]], *G. merluccius* [Leigh-Sharpe[41]], *Macrurus fabricii* [Hansen[23]], *Sebastes marinus* [Hansen[23]], *Somniosus microcephalus* [Hansen[23]], *Sargus rondeletii* [Brian[9]], *Merlangus vulgaris* [Brian[9]], *Blennius gunellus* [Nordmann], *Merlucius sp.* [Heller[26]], *Lycodes frigidus* [Wilson[63]], *Doydixodon fasciatum* [Wilson[63]]; on the gills, within the buccal cavity, on the toungue, in the fold of skin around mouth, and on the fins.

Female: Cephalothorax, from front to the tip of 1st maxillipeds 4.87 long, trunk excluding genital process 3.40×2.40, egg tube 5.56 long (all in mm.); yellowish in alcohol, with egg tubes yellowish to pale brownish. Integument separated from body by a narrow space.

Cephalothorax slightly surpassing trunk in length, of uniform width throughout, straight, or only a trifle curved, and folded back so as to make an angle of about 45° with trunk, but in line with 1st maxillipeds. Head truncate in front, with carapace inconspicuous. Trunk rectangular, with round corners, longer than wide and somewhat depressed dorsoventrally. It carries a short median genital process on caudal margin and a pair of transverse ridges on either side of it.

First antennae 2-jointed; basal joint inflated and apical joint ending in a triangular lobe and a few short setae. Second antennae turned inward at right angles, uniramous, with articulations indistinct except most basal one; apex narrowly round, papillose on outer face along narrow marginal area and furnished with a very short blunt spine on the same face near dorsal side and with 2

Fig. 10. *Clavella uncinata* (O. F. MÜLLER), female. A, female carrying male, ventrolateral view; B, same, ventral view; C, same, dorsal view; D, fore end of cephalothorax, dorsal view; E, same, ventral view; F, 1st antenna and oral parts; G, 1st antenna; H, 2nd antenna, outer view; I, tip of same, outer view; J, same, inner view; K, mandible; L, maxilla; M, 1st maxillipeds; N, 2nd maxilliped; O, claw of same. A–C ×10, D, E ×27, F ×180, G, I, J, O ×340, H ×85, K ×490, L ×375, M ×19, N ×170.

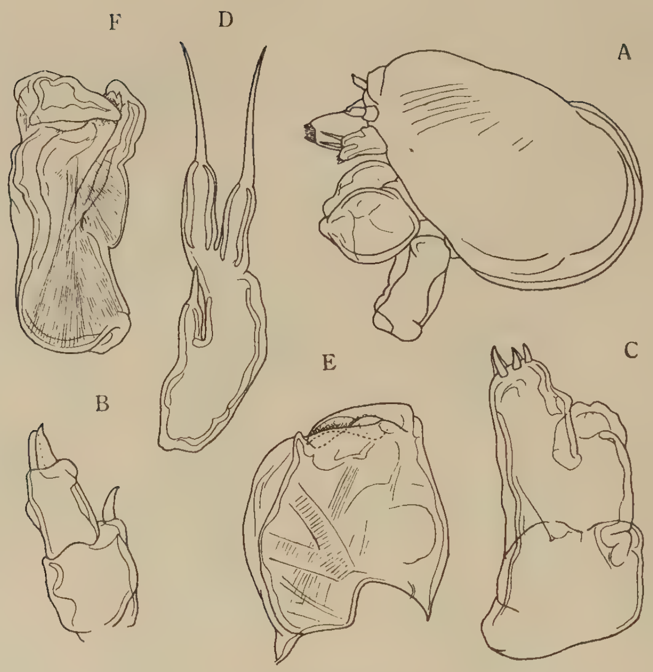

Fig. 11. *Clavella uncinata* (O. F. MÜLLER), male. A, lateral view; B, 1st antenna; C, 2nd antenna; D, maxilla; E, 1st maxilliped; F, 2nd maxilliped. A ×85, B–D ×490, E, F ×200.

adjoining, conically pointed, subterminal ones on the other face. Mandible have 2 principal teeth, which interpose 2 tiny intermediate ones and are followed by another intermediate and 2 secondary ones. Maxillae narrowed proximally, expanded distally, ending in 2 narrow lobes surmounted by pointed spine; one of these lobes associated at base with a short additional spine; palp in the form of a small conical process with bifurcate tip. First maxillipeds very short, tightly coalesced together, and provided with glandular swelling at base and short ducts at center on each side; apex thickened to form ring-like ridge. Second maxillipeds crowded with other cephalic appendages and close to midline. Palm fusiform, having inner margin undulated and fringed by a short row of minute hairs, besides with a short spine standing amid these. Claw nearly straight, ending in sharp terminal spine, which has a rudimentary tooth on inner border and is associated with 2 feebler, unequal spines at base; basal spine of claw short and blunt.

Male: Uncolored, opaque, 0.48×0.32 (in mm.). Ovate in lateral aspect, narrowing forward and well round caudally, without free segments differentiated.

First antennae short, 2-jointed; basal joint with a single spine and distal joint with 2. Second antennae bilobed; exopod rudimentary and shorter than endopod which has 3 apical spines. Proboscis projecting ventrally. Maxillae

slender, bifurcate, each lobe ending in long acuminate spine; palp short, tipped by single spine. First maxillipeds powerful; palm inflated and well round, bearing a short conical process at inner distal angle; claw scarcely curved, with sharp apex, and acting against the inner side of that process of palm. Palm of 2nd maxillipeds slenderer than that of preceding, cylindrical, though more or less irregular on sides, and furnished with a quadrate projection, against whose inner depression triangular, blunt claw shuts. Neither other limbs, nor caudal rami.

Remarks: It has fully been discussed by POULSEN (1939) that LEIGH-SHARPE's *sciatherica*[33] and *iadda*[35], both of which are the parasite of *Gadus morrhua* like *uncinata*, are no more than the different phenotype of *uncinata*. Recently, HEEGAARD (1947), going farther, has reached the conclusion that other species described by LEIGH-SHARPE from the fishes of the genus *Gadus*, i. e. *devastatrix*[36], *typica*[41] and *deliciosa*[41], are all synonymous with *uncinata*.

YAMAGUTI (1939), in his description of *uncinata* obtained from *Gadus macrocephalus*, mentioned the presence of disagreement between his specimens and WILSON's, or T. & A. SCOTT's. As he did not insert any figure, I can not make out to what extent his and my specimens are in accord. At any rate, my specimens are in complete agreement with GUSSEV's (1951) ones, which are parasitic on the same host from the Siberian waters.

Clavella scombropis YAMAGUTI, 1939

(Fig. 12)

YAMAGUTI 1939, pp. 555–556, Pl. 47, Figs. 133–138.

Occurrence: 8 females and 1 male, on *Scombrops boöps* (HOUTTUYN), on inner surface of operculum close to its dorso-posterior corner, at Owase, Mie Pref., by myself, November 19, 1953.

Distribution: Japan. Maisaka, Sizuoka Pref. (YAMAGUTI), on the same host.

Female: Whitish, with pale yellow egg strings; length of cephalothorax 4.75, trunk 1.93×1.25, length of egg string 2.86 (all in mm.).

Cephalothorax folded back at its junction with trunk so as to direct caudally, strongly elongate attaining more than twice the length of trunk, uniform in width, and very flexible. Carapace more or less distinct, small, with front produced into round lobe. Trunk abruptly expanded and slightly increasing in width backward. It is about 3/5 as wide as long, somewhat depressed dorsoventrally, and has gracefully curved anterior shoulders and round caudo-lateral angles. Caudal border produced on the median into an inconspicuous bulge to which egg strings attach. These latter longer than trunk.

Fig. 12. *Clavella scombropis* YAMAGUTI. A–L, female; A, dorsal view; B, fore end of cephalothorax, ventral view; C, 1st antenna; D, 2nd antenna; E, same, apical part, inner view; F, same, outer view; G, mandible; H, maxilla; I, 1st maxillipeds; J, tip of same; K, 2nd maxilliped; L, caudal end; M–S, male; M, lateral aspect; N, 1st antenna; O, 2nd antenna; P, maxilla; Q, 1st maxilliped; R, claw of same; S, claw of 2nd maxilliped. A ×19, B ×170, C, E–H, K, N–P ×490, D, M ×120, I, L ×41, J ×85, Q–S ×410.

First antennae short, cylindrical, with very indistinct articulations, and tipped by a blunt spine. Second antennae turned inward, but not meeting on the midline, uniramous, with a broad, medially directed, transverse expansion on basipod; terminal lobe subdivided into 3 indistinct joints; basal 2 of these wrinkled on outer border and the rest with 2 or 3 vestigial spines. Teeth of mandibles consist of tiny terminal 3 and stronger succeeding 4, of these most basal one being blunt and the next slenderer than others. Maxillae slender, bilobed, each lobe ending in acuminate spine; palp rudimentary, also cut into 2 pointed lobes. First maxillipeds very short, in line with cephalothorax, and entirely fused together to form a conical process, which has a pair of lateral tubercles at base, wrinkles on surface and ends in 2 lip-like laminae; bulla button-shaped. Second maxillipeds crowded with other cephalic appendages and closely adjoining each other on midline. Palm ovate, armed with a short spine at the center of inner border and a small tuberculated area just distally. Claw nearly straight, tipped by robust spine reaching the center of palm, serrated on inner border, and with a short basal spine.

Male: Allotype. Whitish, 0.28 mm. long, 0.18 mm. thick. Oblong ovate, attenuating forward and widely round on caudal margin, convex dorsally and flattened ventrally; without free segments.

First antennae short, 3-jointed, terminating in 3 ordinary and 1 tiny spines. Second antennae biramous, with exopod represented by rudimentary, angular lamella; endopod 2 jointed, basal joint confluent with basipod, and apical joint with 2 minute spines. Proboscis cylindrical, directing ventrally. Maxillae slender, terminating in 2 long sharp spines. First maxillipeds with palm swollen and ovate; distal border of palm undulated and forming a depression at inner angle, against which the tip of sickle-shaped claw closes. Palm of 2nd maxillipeds narrower than that of 1st, oblong, but more or less irregular in outline; terminal claw broad at base, curved and narrowly pointed at end.

Remarks: The present specimens are largely in accord with YAMAGUTI's type, though there are some minor points of differences in the constitution of appendages, especially in the disposition of their spines. Since his material was not accompanied with any male, the description given above is the first one about this sex. This male agrees so much with the same of the type species of the genus, that there leaves no doubt in the propriety of the generic designation of the present species. YAMAGUTI's so-called genital processes are not corresponding to what has been termed by WILSON under this name. These are nothing but the knobs at the bases of the egg tubes, which are yet undeveloped in YAMAGUTI's specimens.

Genus *Clavellopsis* Wilson, 1915

Clavellopsis sargi (Kurz), 1877

(Figs. 13 & 14)

Anchorella sargi, Kurz 1877, pp. 393–396, Pl. 25, Figs. 5 & 6, Pl. 26, Fig. 29, Pl. 27, Figs. 51 & 52; Bassett-Smith 1899, p. 504.
Clavella sargi, Graeffe 1902, p. 14; Brian 1906, p. 113, Pl. 9, Fig. 2.
Clavellopsis sargi, Wilson 1915, p. 687; Yamaguti 1939, pp. 556–557, Pl. 68, Figs. 144–148. As to further bibliography see Brian (1906).

Distribution: Mediterranean (Brian[10]), Adriatic (Kurz[29], Graeffe[26]), Japan (Yamaguti[67]).

Host: *Sargus annularis*, *S. salvianus*, *S. vulgaris* [Brian[10], Kurz[29]], *Sparus longispinis*, *Pagrosomus unicolor* [Yamaguti[67]].

Specimens examined: 8 females and 3 males, on *Sparus macrocephalus* (Basilewsky), at Momotori, Mie Pref., by myself, September 28, 1951. Adhering to the floor of buccal cavity or to the gills.

Female: Length from head to the tip of 1st maxillipeds 3.55, trunk including genital process 2.33×2.28, length of egg strings 2.89 (all in mm.); yellowish brown in preservative, with egg strings darker in color. Thin chitinous integument is separated from the flesh of body by a narrow space filled with transparent fluid.

Cephalothorax cylindrical, inclined dorsally, making an obtuse angle with trunk, which it surpasses in length. Carapace more or less distinct, occupying about 1/3 the length of cephalothorax, widely round in front, and narrowed toward the rear. Trunk depressed dorsoventrally, but expanded laterally, transversely elliptical, being wider than long, with sides somewhat wrinkled, and carrying a short barrel-shaped, median genital process at posterior end. Egg tubes much longer than trunk.

First antennae 4-jointed, with basal joint inflated, while others cylindrical; apical joint tipped with a few short spines. Second antennae turned inward, their apices meeting on the midline, biramous. Exopod linguiform, rugose along outer margin and fringed with triangular papillae; endopod narrower and shorter than exopod, unjointed, and surmounted with 3 short blunt spines. Mandibles edged by 7 blunt, more or less irregularly arranged teeth; secondary and intermediate teeth indistinguishable. Maxillae slender, bilobed, each lobe ending in a sharp spine; palp scarcely projecting and with 2 shorter spines. First maxillipeds very short, fused together, forming ring-like thickening at tip, which holds mushroom-shaped bulla. They are appended, at the base on each side, with 2 large and small gland tubercles as well as with 2 ejection tubes, which are placed one close to the ventral face of cephalothorax and the other near the antero-dorsal angle of trunk. Second maxillipeds crowded with other cephalic

Fig. 13. *Clavellopsis sargi* (KURZ), female. A, dorsal view; B, ventral view, associated with male; C, lateral aspect; D, fore end of cephalothorax, ventral view; E, 1st antenna with oral parts; F, 1st antenna; G, 2nd antenna; H, apical part of same; I, mandible; J, maxilla; K, 1st maxillipeds; L, same, lateral view; M, 2nd maxilliped. A–C ×12, D ×41, E ×85, F, J ×340, G, M ×120, H, I ×490, K, L ×19.

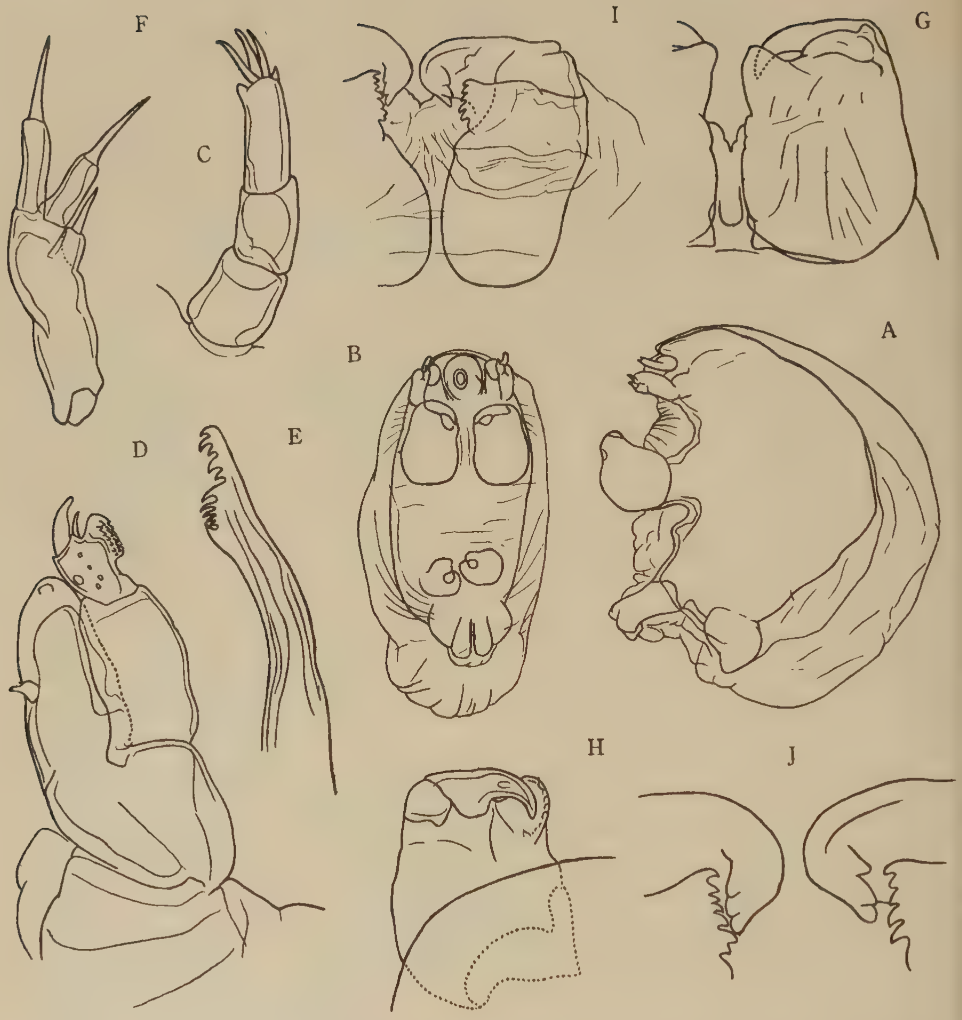

Fig. 14. *Clavellopsis sargi* (KURZ), male. A, lateral view; B, ventral view; C, 1st antenna; D, 2nd antenna; E, mandible; F, maxilla; G, 1st maxilliped; H, same, viewed from anterior side; I, 2nd maxilliped; J, terminal part of same. A, B ×41, C, D, F, J ×340, E ×490, G, H ×120, I ×170.

appendages, and on each side of midline, relatively robust. Their palm oblong ovate, having inner border irregular and provided with a tubercle and a short spine at about its middle. Claw only slightly curved, reinforced with stouter principal and feebler accessory spines at apex, besides carrying another tiny one at about the center.

Male: Brownish, surrounded by broad transparent space between external chitin and body flesh; length 1.25, width 0.61, thickness 0.92 (all in mm.). Strongly convex dorsally, but insensibly concave ventrally, and somewhat compressed laterally. Cephalothorax occupies far greater part of body, 2nd maxil-

lipeds being removed toward caudal end, where it carries short conical free segment. The latter 4-lobed in dorsal aspect, median crevice indicating anal opening.

Cephalic appendages and proboscis projecting ventrally. First antennae cylindrical, 3-jointed, and tipped by 3 stout and 2 rudimentary spines. Second antennae bilobed. Exopod elongate lamellar, narrowly round at apex, inseparable from basipod at base, furnished with a crescentic subterminal papilla and with a short triangular spine on dorsal margin. Endopod extending beyond exopod, 2-jointed, with proximal joint much longer than distal joint and distinct from basipod; distal joint armed with 2 stout and feeble apical spines, and expanded on ventral border in quadrate plate showing a file-like surface, besides scattered by a few tubercles further internally. Blade of mandibles divided into narrower distal and broader proximal portions; the former with 2 longer teeth alternating with shorter teeth which are present in 3, and the latter cut into 6 teeth successively decreasing in size proximally; proximalmost of these again enlarged and turned distally unlike others. Maxillae bilobed, each lobe terminating in sharp spine; palp short and with a single spine. First maxillipeds robust; palm quadrate, with a round inner distal projection, into whose inner depression beak-like claw fits. Palm of 2nd maxillipeds slender, much longer than wide, quadrate, with inner-distal denticulate lamina; claw strongly curved, with apex tripartite and acting against the denticles of palm. Neither other limbs, nor caudal rami.

Remarks: Except in some minor points, Japanese specimens are largely in accord with those described by KURZ[29] from the Mediterranean. As YAMAGUTI's specimens were not accompanied with the male, this is the first record of this sex from our waters, which conforms also with description and figure given by KURZ in all essential points. It may be felt to be improbable that the same species can ever occur from such remote localities showing discontinuous distribution. In my mind, however, it seems better to retain the name *sargi* for the Japanese parasite until something more will be known about the Mediterranean specimen.

Clavellopsis flexicervica n. sp.

(Fig. 15)

Occurrence: 5 females, no male, on *Abdefduf natatus* DAY, at Seto, Wakayama Pref., by myself; attached to soft fleshy part of gill arches.

Female: Holotype. Length of cephalothorax 3.50, trunk 1.33×1.24, egg cases 0.80×0.55 (all in mm.); pale yellowish, translucent in alcohol, with brighter yellow egg cases. Integument strongly rugose and separated from the flesh of body by a narrow space.

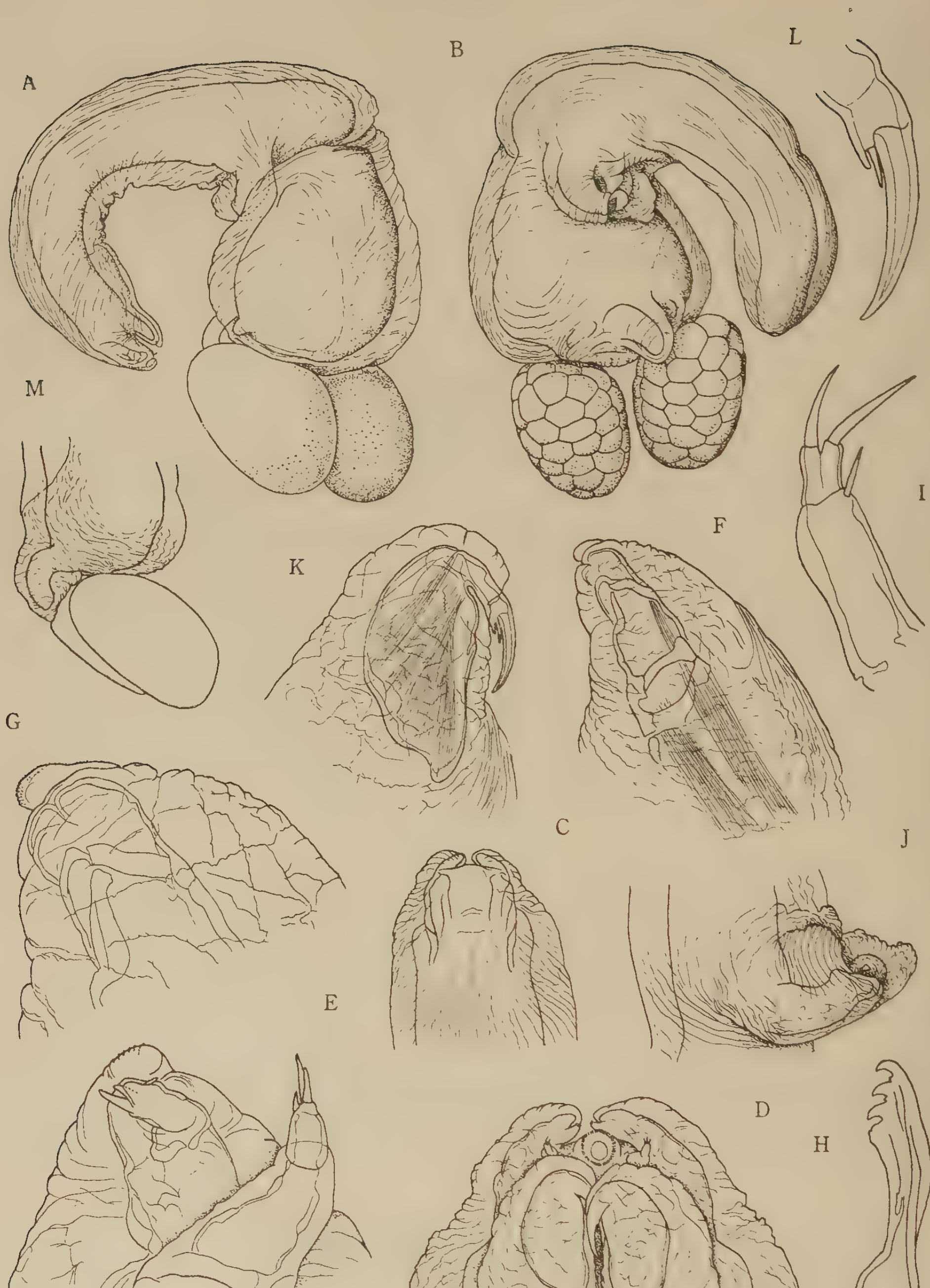

Fig. 15. *Clavellopsis flexicervica* n. sp., female. A, lateral aspect; B, ventral aspect; C, fore end of cephalothorax, dorsal aspect; D, same, ventral aspect; E, 1st antenna and inner side of 2nd antenna; F, 2nd antenna, outer side; G, exopod of same; H, mandible; I, maxilla; J, 1st maxillipeds; K, 2nd maxilliped; L, claw of same; M, caudal end of body, lateral view. A, B, M ×27, C ×52, D ×120, E, G, L ×490, F, H, I, K ×205, J ×41.

Cephalothorax elongate and flexible, turning ventro-caudally, much longer than trunk, and uniform in width except in cephalic region, which is truncate in front and devoid of any indication of carapace. Posterior end of cephalothorax bordered from trunk by a deep furrow which extends from dorsal side toward lateral side in a horse-shoe-shape. Trunk triangular, widening backward, only slightly longer than wide, relatively thick dorsoventrally, and with well-round caudo-lateral angles. A short corniform genital process protrudes over ventral surface of trunk at caudal end on midline.

First antennae 2-jointed; proximal joint swollen, occupying greater part of their length and distal joint tipped with 3 spines. Second antennae turned inward, but not meeting each other on midline, bilobed; exopod with apex round and finely spinulose; endopod indistinctly 2-jointed, terminating in a triangular lobe and a few spines. Mandibles bear 3 principal teeth, interposing a rudimentary intermediate tooth between consecutive ones. Maxillae divided a short distance behind apex into 2 subjoints; distal subjoint bilobed, ending in 2 long pointed spines; palp represented by a single feeble spine locating at the end of proximal subjoint. First maxillipeds situated at posterior end of cephalothorax, very short, and separated to the end, where chitinous integument forms a cup-like depression. Second maxillipeds near anterior end of cephalothorax; palm fusiform, unarmed; claw reaching the center of palm, armed with long falciform terminal spine which is associated with 2 spines at base. Egg cases very short, plump and ovoidal.

Remarks: The new species agrees with the generic definition of *Clavellopsis* given by WILSON in all essential points except the possession of the 2-jointed antennules and the distinctness of the 1st maxillipeds. Difference in the number of joints composing the antennule is of minor importance. The 1st maxillipeds are entirely coalesced together in all of the species which were assigned by that author to the genus when he erected it [i.e. *laciniata* (KRØYER)[60], *fallax* (HELLER)[24, 25], *sargi* (KURZ)[29], *robusta* (WILSON)[62], *paradoxa* (van BENEDEN)[52], *strumosa* (BRIAN)[10], and *producta* WILSON[62]]. The six species described by YAMAGUTI[67] from Japan also show a similar character. On the other hand, in BERE's *longimana*[6] and in his specimens of *strumosa* (BRIAN), this pair of appendages are completely separated. It does not appear, therefore, unreasonable to assign the new parasite to *Clavellopsis*, though a more difinite position may be revealed by the male which is now unknown to us. The new species can be discriminated from *strumosa* and *longimana*, for the first ground, by its plump trunk and short ovoidal egg cases. The shape of egg cases reminds us of that of *laciniata*, which, however, has the cephalothorax bent dorsally instead of ventrally.

Clavellopsis pellucidula n. sp.

(Fig. 16)

Occurrence: A single female without male, on *Chlorophthalmus albatrossi* JORDAN & STARKS, at Owase, Mie Pref., by K. SUZUKI, October 21, 1950; attached to pelvic fin.

Fig. 16. *Clavellopsis pellucidula* n. sp., female. A, cephalothorax in dorsal view, trunk in ventral view; B, cephalothorax in ventral view, trunk in dorsal view; C, 1st antenna; D, maxilla. A, B ×27, C, D ×340.

Female: Holotype, a premature stage. Whitish, semitransparent in alcohol, cephalothorax 2.12 long, 1st maxillipeds 1.05 long, trunk 1.45×0.80 (all in mm.). External chitin separated from the flesh of body by a narrow space.

Cephalothorax elongate, folded back and trailed caudally alongside of trunk, beyond which it extends. It is of uniform width throughout, except bluntly narrowed anterior end. Carapace indistinct. Trunk oblong ovate, longer than wide, and somewhat depressed dorsoventrally; caudal end has a median genital process in the form of round boss, on whose dorsal side there are a pair of small protuberances closely adjoining together on midline and another larger pair just outside these. The protuberances represent the sites of attachment of egg tubes which are undeveloped in the present material.

First antennae cylindrical, 2-jointed; basal joint with a single spine and apical joint with a few terminal ones. Second antennae turned inward and

overlapping each other, biramous. Maxillae bilobed, each lobe ending in a sharp spine. First maxillipeds in line with cephalothorax, arising from its junction with trunk, and attaining half its length. They are fused together to form a cylinder tapering to tip, but have line of fusion more of less retained; ducts of glands well defined on either side close to their bases. Bulla mushroom-shaped. Second maxillipeds crowded together with other cephalic limbs, close to each other at midline, and composed of oval palm and falciform claw.

Remarks: As the dissection of the sole specimen was undesirable, a full account on the structure of the appendages has not been given. The specimen is in a somewhat young stage and is not associated with the male. The description given above, however, clearly indicates that it can most appropriately be assigned to the genus *Clavellopsis* It is distinguished from the species so far known in the genus by the 2-jointed antennules and by the elongate adhesive arms. It bears a certain resemblance to *longimana* BERE[6] in the possession of elongate arms, but the difference is found in that its cephalothorax is bent to such an extent as to become almost parallel with the trunk.

Genus *Epibrachiella* WILSON, 1915

Epibrachiella septicauda n. sp.

(Figs. 17 & 18)

Occurrence: 7 females and 2 males, on *Doederleinia berycoides* (HILGENDORF), at Owase, Mie Pref., by myself, December 9, 1952; adhering to the skin of buccal floor or to gill arches.

Female: Holotype. Color yellowish in alcohol, with egg strings yellowish to pale yellowish brown; cephalothorax 5.10 long, trunk exclusive of posterior processes 1.86×1.48, egg tubes 1.38 long (all in mm.). External chitin detached from the flesh in cephalothorax and arms and traversed by parallel longitudinal rugae.

Cephalothorax strongly flexed ventrally as well as to one side of body, elongate, and of uniform width. Carapace more or less distinct, truncate in front, widening backward through a slight central contraction. Trunk much shorter than cephalothorax, ovoidal in lateral aspect, but nearly rectangular in dorsal aspect, slightly narrowing forward and with undulated sides. Caudal end of trunk carries a short conical genital process on ventral side on the median, a pair of longer corniform, ventrally curved processes on dorsal level and on either side of midline, and 2 pairs of shorter mammiform processes on lateral sides, disposed one on dorsal and the other on ventral levels. Egg tubes elongate oval, much shorter than trunk.

First antennae cylindrical, curved, attenuating toward tip, 4-jointed; 2nd joint with a single subterminal spine and 4th joint tipped by 3 unequal spines as

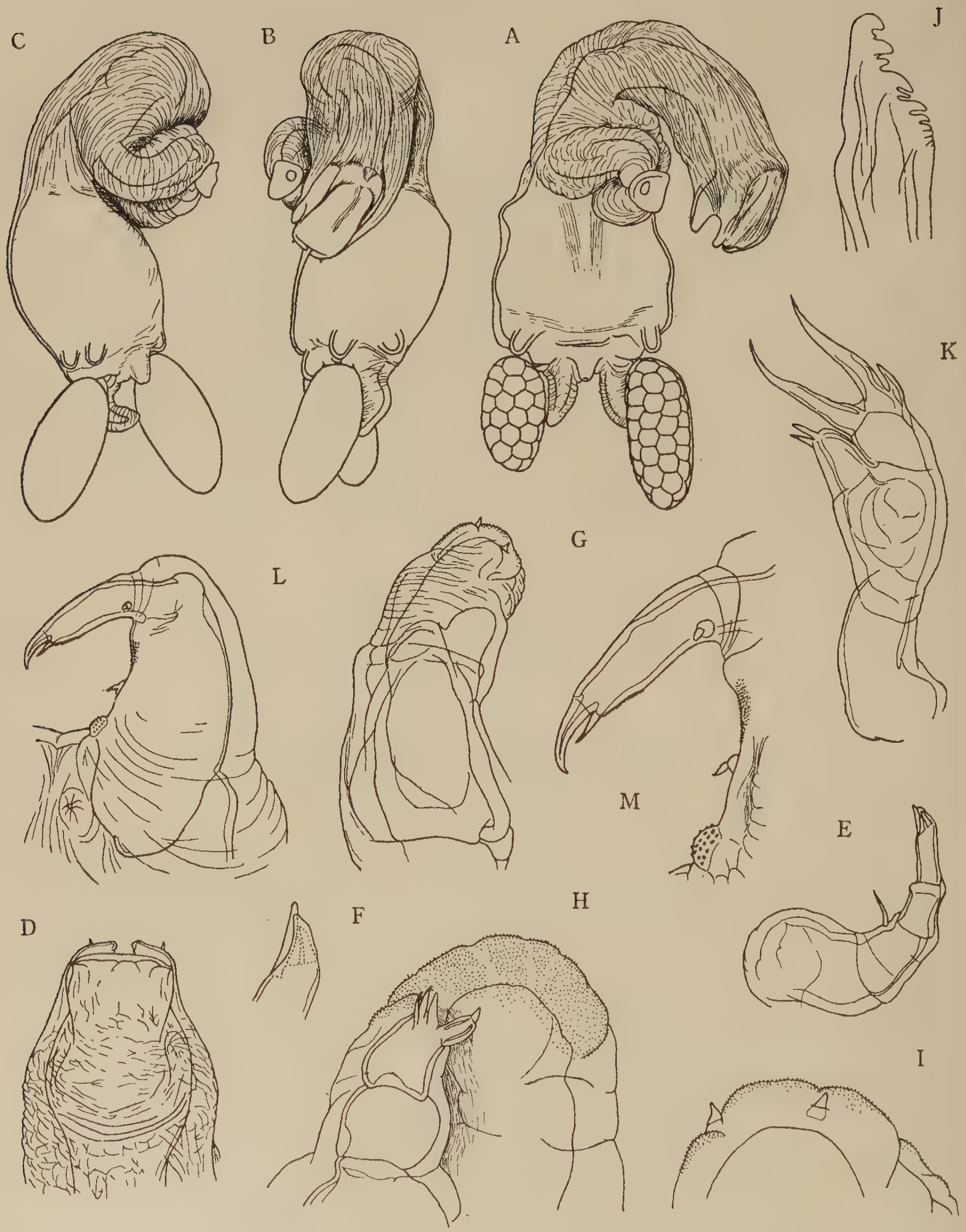

Fig. 17. *Epibrachiella septicauda* n. sp., female. A, ventral view; B, right side view; C, left side view; D, fore end of cephalothorax; E, 1st antenna; F, tip of same; G, 2nd antenna; H, same, inner side; I, exopod of same, outer side; J, mandible; K, maxilla; L, 2nd maxilliped; M, claw of same. A–C ×14, D ×27, E, M ×205, F, H–J ×490, G ×170, K ×340, L ×120.

well as by a triangular lamina. Second antennae turning inward, their tips not meeting each other; biramous. Exopod broad, widely round but with 5 or 6 very shallow indentations on apical margin, densely granulose on inner face along marginal area, and bearing 2 short triangular spines on outer face. Endopod shorter and narrower than exopod, columnar, 2-jointed; distal joint granulose on outer terminal margin and tipped with 3 feebler and 1 stouter spines. Mandibles possess 4 principal teeth, every consecutive 2 of which interpose a tiny intermediate one; secondary teeth succeeding them 4 or 5 in number, very feeble, and closely adjoining together. Maxillae ending in a long acuminate spine and accompanying a much shorter rudimentary one on outer side; palp triangular, tipped by 2 short spines. First maxillipeds placed at posterior end of cephalothorax, short and separate, but somewhat twisted with each other. They bear at their bases on lateral sides a pair of rather inconspicuous swellings of secretory glands and their tips are united to hold between each other the stalk of bulla which has the shape of a triangular disc. Second maxillipeds close to other cephalic appendages. Palm elongate fusiform; inner border slightly concave, with a small round, tuberculated bulge at base and a short spine surmounting on a papilla at center, and finely granulose on a narrow subterminal area. Claw almost straight, reinforced at tip with a stout terminal and a feebler accessory spines, finely serrated on inner border just behind, and bearing a very tiny blunt spine at base.

Male: Allotype. Whitish, 1.19 mm long, 0.68 mm thick; external chitin finely wrinkled and separated from flesh of body by a spacious fluid lumen.

Carapace distinct from trunk, triangular in lateral aspect, strongly convex dorsally, being highest at posterior region, and flattened ventrally. Trunk cylindrical, taking up more than half of entire length and abruptly narrower than cephalothorax, from whose posterior surface it extends straight backward. It is somewhat contracted at fore end to form a waist, has a narrowed hind end and lacks segmentation entirely.

Cephalic appendages and proboscis protruding ventrally. First antennae 4-jointed; 2nd joint with 1 spine and 4th joint with 3 terminal and 1 curved, subterminal spines. Second antennae biramous. Exopod linguiform, with a single triangular spine on outer border. Endopod extending much beyond exopod, 2-jointed; proximal joint tuberculated on a narrow crescent area along ventral border and distal joint with a finely serrated ventral expansion and tipped by curved, stouter spine as well as straight, feebler ones. Maxillae deeply bifurcate ending in acuminate spines, and with a rudimentary outer spine; palp rod-shaped, with 2 short spines. Palm of 1st maxillipeds ovoidal, bearing a triangular, inner distal process which is covered with fine granules on its inner surface; claw slender but well curved. Second maxillipeds placed close to preceding limbs; palm nearly a quadrangle, with a triangular, somewhat trilobed process

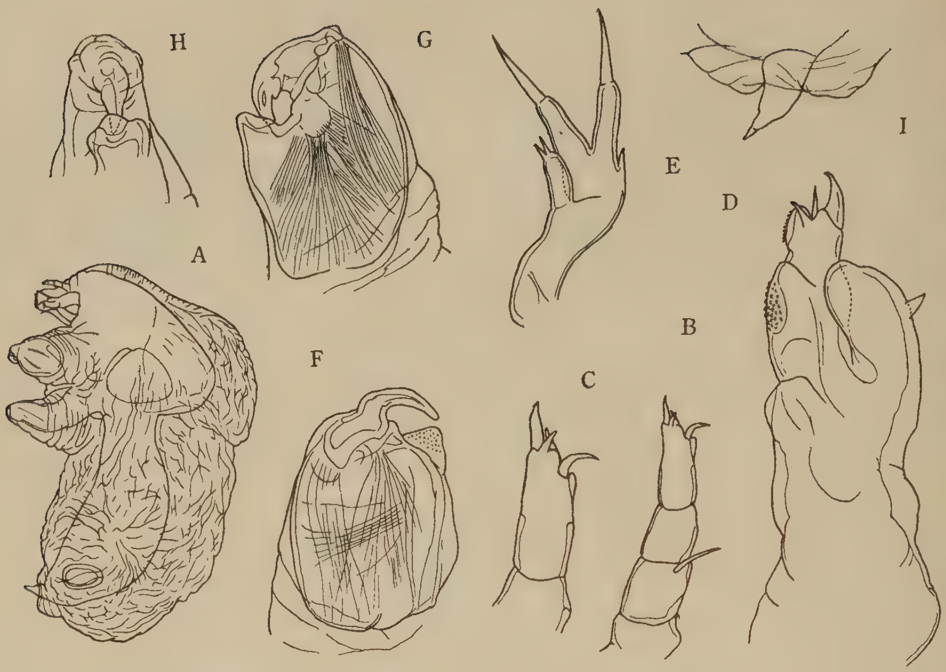

Fig. 18. *Epibrachiella septicauda* n. sp., male. A, lateral view; B, 1st antenna; C, tip of same; D, 2nd antenna; E, maxilla; F, 1st maxilliped; G, 2nd maxilliped; H, tip of same, inner view; I, caudal ramus. A ×41, B, E ×340, C, D ×490, F–I 170.

at inner distal angle; claw robust, strongly curved like a beak and fitting into the inner depression of the named process of palm.

Remarks: *Epibrachiella* comprises few species. The new species is more nearly allied to *hoplognathi* Yamaguti[67] already recorded from Japan than to the well-known species *impudica* (Nordmann)[10, 17, 40, 52] in having 3 pairs of posterior processes in addition to the genital one. It may be discriminated from *hoplognathi* by that the longest pair of the processes are situated on the dorsal side of the trunk instead of the ventral side and by that all the pairs are relatively shorter than in Yamaguti's species. In the character of the 2 pairs of antennae and of the maxillae, the two are very similar.

Epibrachiella exilis n. sp.

(Fig. 19)

Occurrence: A female and a male, on *Kyphosus lembus* (C. & V.) at Nagaturo, Izu Peninsula, Sizuoka Pref., by myself, June 25, 1943; adhering to gills.

Female: Holotype. Dusty yellow-brown in preservative; total length 4.79, length of cephalothorax 1.80, trunk exclusive of caudal processes 1.64×0.93,

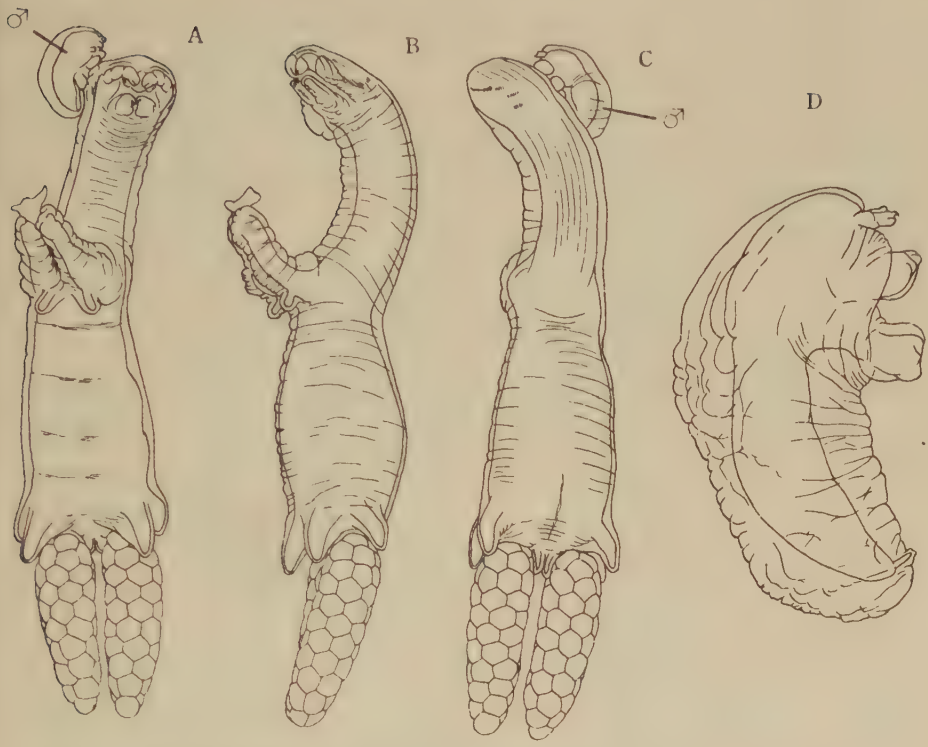

Fig. 19. *Epibrachiella exilis* n. sp. A, female with male, ventral aspect; B, same, lateral aspect; C, same, dorsal aspect; D, male, lateral aspect. A–C ×19, D ×85.

length of egg tubes 1.36 (all in mm.). External chitin with transverse rugae, and released from flesh, a narrow space intervening between them.

Body almost straight. Cephalothorax in line with trunk, but somewhat flexed dorsally at the junction with the latter and making a slight ventral curvature further forward. It is elongate, about as long as trunk, relatively thick, and of uniform width throughout its length, though widened a little at the base of 1st maxillipeds. Carapace indistinct. Trunk slender, cylindrical, gradually continuous from cephalothorax without showing any abrupt expansion, and insensibly widening backward. Caudal end furnished with 2 pairs of short conical, lateral processes, arranged dorsiventrally, and with another much shorter dorsal pair, whose members are closely adjoining each other on midline. Egg tubes shorter than trunk.

First antennae 3-jointed. Second antennae turned inward, with apices meeting on midline, biramous, and with 2-jointed endopod. Maxillae bipartite. First maxillipeds projecting from posterior end of cephalothorax ventro-anteriorly, moderately long, less than half as long as the latter; members of both sides adjoining each other, but separated to apex, and with a gland duct on posterior

side close to the base. Second maxillipeds placed near anterior end of cephalothorax, prehensile as usual.

Male: Allotype. Color same as in female, 0.69 mm. long, 0.33 mm. thick, similar to the male of *E. septicauda* in general constitution. External chitin rugose on surface, detached from the flesh of body by the interposition of a spacious fluid lumen.

Cephalothorax more than 1/3 as long as entire length, arched on dorsal side. Its posterior boundary indicated dorsally by a shallow surface groove and ventrally by the rectangle made at the base of 2nd maxillipeds. Trunk slender, tapering caudally through a somewhat swollen intermediate region.

Cephalic limbs and proboscis projecting ventrally. First antennae 3-jointed. Second antennae biramous; endopod with a stout, curved spine. Maxillae bipartite. Two pairs of maxillipeds close together, 1st pair with oval palm, whereas 2nd pair with quadrate one. No leg rudiments. Caudal rami short, foliaceous, projecting ventrally at right angles to trunk surface.

Remarks: The present species is allied to *hoplognathi* Yamaguti[67] in the general outline of the female body, but is different in the disposition of caudal processes. Yamaguti's species possesses the rather long ventro-median pair of processes in addition to the shorter lateral and dorsal pairs which are about as long as the 2 lateral pairs of the present species. The median pair arises from the dorsal side of trunk in the present species and is much shorter than in *hoplognathi*. The males of the two new species here described are in conformity with each other in their general constitution. In order to avoid the mutilation of the single couple included in the collection, further detailed study of the appendages has not been made.

Genus *Parabrachiella* Wilson, 1915

Parabrachiella incurva n. sp.

(Fig. 20)

Occurrence: 2 females, on *Kyphosus lembus* (C. & V.), at Nagaturo, Izu Peninsula, Sizuoka Pref., by myself, June 25, 1943; 1 female on the same host, at Seto, Wakayama Pref., by myself, April 21, 1954; adhering to gills. One of the females from the former locality has been selected as holotype.

Female: Color in alcohol brownish, with egg strings dusty brown; cephalothorax 2.28 long, trunk 1.57×1.15, egg tube 1.60 long (all in mm.). External chitin slightly detached from cephalothorax and from ventral side of trunk; more or less rugose.

Cephalothorax elongate, curved, and inclined ventrally, making an obtuse angle with trunk, from which it is bordered by a ring of shallow groove. Carapace more or less distinct, triangular, having frontal margin truncate and sides

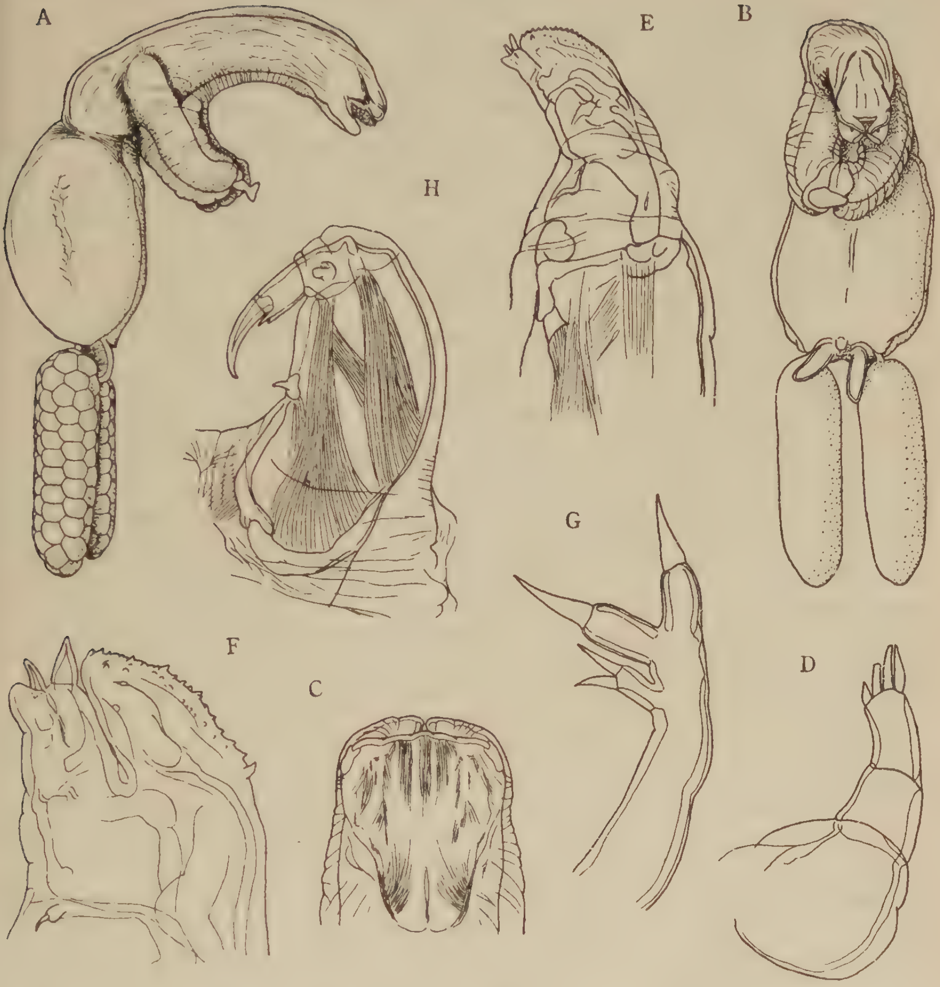

Fig. 20. *Parabrachiella incurva* n. sp., female. A, lateral view; B, ventral view; C, carapace, dorsal view; D, 1st antenna; E, 2nd antenna; F, apical part of same; G, maxilla; H, 2nd maxilliped. A, B ×19, C ×52, D, F, G ×490, E, H ×170.

converging backward. Trunk elongate oval in lateral aspect, nearly quadrangular in dorsal aspect, shorter than cephalothorax, and furnished on either side of midline at caudal end with a short narrow, finger-shaped processes, besides with a papilliform, rudimentary, median genital process. Egg cases about as long as trunk.

First antennae 3-jointed, composed of swollen basal and cylindrical succeeding joints, and tipped by 4 spines. Second antennae turning inward so as to meet on the midline, biramous; exopod triangular, with dorsal margin covered by rows of pointed papillae, endopod very indistinctly 2-jointed, ending in 2 thick, conical spines and bearing a triangularly blunt terminal lobe. Maxillae

slender, deeply bilobed, each lobe surmounted with a stout, acuminate spine; palp short, rod-like, carrying 2 feebler spines. First maxillipeds displaced toward posterior end of cephalothorax to which they stand at right angles; they are not very long and completely separated from each other except at tips. Second maxillipeds locating close to other cephalic limbs; palm twice as long as wide, with convex outer and concave inner borders, and with a short but sharp spine at about the center of outer border; claw not much curved, armed with a rather long principal and 2 very short accessory spines at tip and with short blunt spine at base.

Remarks: The new species is characterized above all things by that the 1st antennae are 3-jointed, that the endopod of the 2nd antennae are indistinctly jointed, and that the maxillae are bipartite. Although Wilson (1915) defined the maxillae of *Parabrachiella* as being bipartite, those of all hitherto known species [*rostrata* (Krøyer)[52, 62, 63], *insidiosa* (Heller)[17, 27, 52], and *australis* Wilson[64]] possess an additional, rudimentary spine on the outer side. The new species appears to be the closest to *rostrata* in having 2 ventro-posterior processes which are present 4 in others. The characters of the appendages alluded just above and the relatively shorter trunk in the new species may serve to distinguish it from *rostrata*.

References

1. Bassett-Smith, P. W., 1896a. Notes on the parasitic Copepoda of fish obtained at Plymouth, with description of new species. Ann. Mag. Nat. Hist., (6), Vol. 18, pp. 8-16, Pls. 3-6.
2. ———, 1896b. A list of parasitic Copepoda of fish obtained at Plymouth. J. Mar. Biol. Assoc., N. S., Vol. 4, pp. 153-163.
3. ———, 1899. A systematic description of parasitic Copepoda found on fishes, with an enumeration of the known species. Proc. Zool. Soc. London, 1899, pp. 438-507, Pl. 26.
4. van Beneden, G. J., 1851. Recherches sur quelques crustacés inférieurs. Ann. Sci. Nat., (3) Zool., Vol. 16, pp. 71-131, Pls. 2-6.
5. Bere, R., 1930. The parasitic copepods of the fish of the Passamaquoddy Region. Contr. Canad. Biol. Fish., new ser., Vol. 5, pp. 423-430.
6. ———, 1936. Parasitic copepods from Gulf of Mexico fish. Amer. Midl. Nat., Vol. 17, pp. 577-625.
7. Brian, A., 1901. Caso di anomalia verificatosi su di una "*Brachiella*" del Tonno. Boll. Mus. Zool. Anat. Comp. Univ. Genova, No. 104, pp. 1-3.
8. ———, 1902. Note su alcuni crostacei parassiti dei pesci del Mediterraneo. Ibid., No. 115, pp. 1-16, Pl. 1.
9. ———, 1903. Sui copepodi parassiti di pesci marini dell'Isola d'Elba. Atti. Soc. Ligustica, Sci. Nat. e Geogr., Vol. 13, pp. 1-8.
10. ———, 1906. Copepodi parassiti dei pesci d'Italia, pp. 1-187, Pls. 1-21, Genova.
11. ———, 1908. Note préliminaire sur les copépodes parasites des poissons provenant des Campagnes scientifiques de S. A. S. le Prince Albert 1er de Monaco ou déposés dans les collections du Musée Océanographique. Bull. l'Inst. Ocean., No. 110, pp. 1-18.

12. BRIAN, A., 1912. Copépodes parasites des poissons et des échinides provenant des Campagnes scientifiques de S. A. S. le Prince Albert 1er de Monaco. Res. Camp. Sci. par Albert 1er Prince de Monaco, Fasc. 38, pp. 1–58, Pls. 1–12.

13. CAPART, A., 1941. Résultats scientifiques des croisiéres du nabire-école Belge "Mercator", Vol. 3: V, Copépoda parasitica. Mem. Mus. Roy. d'Hist. Nat. Belg., (2) Fasc. 21, pp. 171–197.

14. ———, 1946. Notes sur les copépodes parasites. A propos de *Charopinus pastinacae* (P. J. VAN BENEDEN, 1851) parasite de *Dasybatis pastinacus* (L.). Bull. Mus. Roy. d'Hist. Nat. Belg., Vol. 22, No 10, pp. 1–6.

15. ———, 1953. Quelques copépodes parasites des poissons marins de la région de Dakar. Bull. d'Inst. Fr. d'Afr. Noire, Vol, 15, pp. 647–671.

16. CAUSEY, D., 1953. Parasitic Copepoda of Texas coastal fishes. Publ. Inst. Mar. Sci., Vol. 3, pp. 1–16.

17. DELAMARE-DEBOUTTEVILLE, C., 1949. Copépodes parasites des poissons de Banyuls (1° Sér.). Vie et Milieu, Vol. 1, pp. 305–309.

18. ——— and NUNES-RUIVO, L., 1954. Copépodes parasites des poissons Mediterranéens (3° Sér.) (I). Ibid., Vol. 4, pp. 201–218.

19. GNANAMUTHU, C. P., 1950. *Lernaeopoda stromatei* n. sp., a copepod parasite of the grey pomfret. Proc. Ind. Acad. Sci., Vol. 31, pp. 175–180.

20. GRAEFFE, E., 1902. Übersicht der Fauna des Golfes von Triest nebst Notizen über Vorkommen, Lebensweise, Erscheinungs- und Laichzeit der einzelnen Arten: V, Crustacea. Arb. Zool. Inst. Wien, Vol. 13, pp. 3–17.

21. GUIART, J., 1913. Crustacés commensaux et parasites de la baie de Concarneau. Bull. Inst. Océanogr. Monaco, No. 264, pp. 1–11.

22. Гусев, А. В., (Gussev, A.) 1951. Паразитические Copepoda с Некоторых Морских рыб. Паразит. сборн. Зоолог. Инст. Акад. Наук СССР, Vol. 13, pp. 394–463.

23. HANSEN, H. J., 1923. Crustacea Copepoda II, Copepoda parasita. Dan. Ingolf-Exped., Vol. 3, No. 7, pp. 1–92, Pls. 1–5.

24. HEEGAARD, P. E., 1943. Parasitic copepods mainly from tropical and antarctic seas. Ark. f. Zool., Vol. 34A, No. 18, pp. 1–37.

25. ———, 1945. Some parasitic copepods from fishes in the Uppsala University collections. Ibid., Vol. 35A, No. 18, pp. 1–27.

26. ———, 1947. Contribution to the phylogeny of the arthropods: Copepoda. Spolia Zool. Mus. Hauniensis, Vol. 8, pp. 9–227, Pls. 1–27.

27. HELLER, C., 1865. Crustaceen. Reise der Österreichischen Fregatte Novara um die Erde, Zool. Theil, Vol. 2, Pt. 3, pp. 1–280, Pls. 1–25, Wien.

28. KIRTISINGHE, P., 1935. Parasitic copepods of fish from Ceylon. Parasitol., Vo. 27, pp. 332–344.

29. KURZ, W., 1877. Studien über die Familie der Lernaeopodiden. Z. Wiss. Zool., Vol. 29, pp. 380–428, Pls. 25–27.

30. LEIGH-SHARPE, W. H., 1916. *Lernaeopoda scyllicola* n. sp., a parasitic copepod of *Scyllium canicula*, part 1. Parasitol., Vol. 8, pp. 262–273.

31. ———, 1918a. *Lernaeopoda scyllicola* n. sp., a parasitic copepod of *Scyllium canicula*, part 2. Ibid., Vol. 11, pp. 18–28.

32. ———, 1918b. *Lernaeopoda globosa* n. sp., a parasitic copepod of *Scyllium canicula*. Ibid., Vol. 11, pp. 29–34.

33. ———, 1918c. *Clavella sciatherica* n. sp., a parasitic copepod of *Gadus morrhua*. Ibid., Vol. 11, pp. 118–126.

34. ———, 1919. The genus *Lernaeopoda*, including a description of *L. mustelicola* n. sp., remarks on *L. galei* and further observations on *L. scyllicola*. Ibid., Vol. 11, pp. 256–266.

35. ———, 1920. *Clavella iadda* n. sp., a parasitic copepod of *Gadus morrhua*. J. Mar. Biol. Assoc. U. Kingd., Vol. 12, pp. 332–338.

36. Leigh-Sharpe, W. H., 1925. A revision of the British species of *Clavella* (Crustacea, Copepoda), with a diagnosis of new species: *C. devastatrix* and *C. invicta*. Parasitol., Vol., 17, pp. 194–200.

37. ———, 1926a. *Ommatokoita superba* n. g. et sp., a parasitic copepod of *Somniosus microcephalus*. Ibid., Vol. 18, pp. 224–229.

38. ———, 1926b. A list of parasitic Copepoda found at Plymouth, with a note on the bulla of *Clavella devastatrix*. Ibid, Vol. 18, pp. 384–386.

39. ———, 1928. The genera *Charopinus* and *Lernaeopodina* (Copepoda) as represented by the collection in the British Museum. Ibid., Vol. 20, pp. 273–297.

40. ———, 1930. Further remarks on the genus *Lernaeopoda*, including a description of a new species *L. bivia*. Ibid., Vol. 22, pp. 137–142.

41. ———, 1933. A second list of parasitic Copepoda of Plymouth with a description of three new species. Ibid., Vol. 25, pp, 113–118.

42. ———, 1935. *Epibrachiella impudica* (Nordmann) (Copepoda). Ibid., Vol. 27, pp. 101–106.

43. Miculicich, M., 1904. Ein neuer Lernaeopodide. Zool. Anz., Vol. 28, pp. 47–52.

44. ———, 1905a. Zur Kenntnis der Gattung *Brachiella* Cuv. und der Organisation der Lernaeopodiden. Ibid., Vol. 28, pp. 599–620.

45. ———, 1905b. Weitere Mitteilungen zur Kenntnis der Gattung *Brachiella* Cuv. Ibid., Vol. 28, pp. 733–736.

46. Milne-Edwards, H., 1836–40. Histoire naturelle des crustacés: Sous-classe des crustacés suceurs, pp. 432–529, Pls. 38–41, Paris.

47. Olsson, P., 1869. Prodromus faunae copepodorum parasitantium Scandinavie. Lund. Univ. Års., Vol. 5, pp. 1–49, Pls. 1–2.

48. Poulsen, E. K., 1939. Investigation upon the parasitic copepod *Clavella uncinata* (O. F. Müller) in Danish waters. Vidensk. Meddl., Vol. 102, pp. 223–244.

49. Scott, A., 1928. The copepod parasites of Irish sea fishes. Rep. Lancashire Sea Fish. Lab., 1928, pp. 81–118, Pl. 1.

50. Scott, T., 1897. The marine fishes and invertebrates of Loch Fyne. 15th Ann. Rep. Fish. Board Scotl., pp. 107–172, Pls. 1–3.

51. ———, 1900. Notes on some crustacean parasites of fishes. 18th Ann. Rep. Fish. Board Scotl., pp. 144–188, Pls. 5–8.

52. ——— and Scott, A., 1913. The British parasitic Copepoda, 2 vols., pp. i-x, 1–252, Pls. A.B, 1–72, London.

53. Sproston, N. G. and Hartley, P. H. T., 1941. The ecology of some parasitic copepods of Gadoids and other fishes. J. Mar. Biol. Assoc. U. Kingd., Vol. 25, pp. 361–392.

54. Steenstrup, J. J. S. and Lütken, C. F., 1861. Bidrag til kundskab om det aabne havs Snyltekrebs og Lernaeer. Vid. Selsk. 5 Raekke Naturw. Math. Afh., Vol. 5, pp. 343–432, Pls. 1–15.

55. Stenta, M., 1904. *Thynnicola ziegleri* Miculicich = *Brachiella thynni* Cuv. Zool. Anz., Vol. 28, pp 345–347.

56. Stephensen, K., 1943. The zoology of East Greenland. Marine Ostracoda, parasitic and semi-parasitic Copepoda and Cirripedia. Medd. Grønland, Vol. 121, No. 9, pp. 1–24.

57. Thompson, C., 1893. Revised report of the Copepoda of Liverpool Bay. Trans. Liverpool Biol. Soc., Vol. 7, pp. 175–230, Pls. 15–35.

58. Thomson, G. M., 1889. Parasitic Copepoda of New Zealand with descriptions of new species. Trans. N. Zeal. Inst., Vol. 22, pp. 353–375, Pls. 25–28.

59. Vogt, C., 1877. Recherches côtières. Arch. Zool. Exp. Gén., Vol. 6, pp. 385–456.

60. Wilson, C. B., 1908. North American parasitic copepods: A list of those found upon the fishes of the Pacific coast with descriptions of new genera and species. Proc. U. S. Nat. Mus., Vol. 35, pp. 431–481, Pls. 66–83.

61. WILSON, C. B., 1913. Crustacean parasites of West Indian fishes and land crabs, with descriptions of new genera and species. Ibid., Vol. 44, pp. 189–277, Pls. 18–53.
62. ———, 1915. North American parasitic copepods belonging to the Lernaeopodidae, with a revision of the entire family. Ibid., Vol. 47, pp. 565–729, Pls. 25–56.
63. ———, 1922. Parasitic copepods in the collection of the Zoological Museum, Kristiania. Medd. Zool. Mus. Kristiania, Vol. 60, No. 4, pp. 1–7.
64. ———, 1923a. Parasitic copepods in the collection of the Riksmuseum at Stockholm. Ark. f. Zool., Vol. 15, pp. 1–15, Pls. 1–2.
65. ———, 1923b. New species of parasitic copepods from southern Africa. Gdgs. K. Vet. Vitt. Samh. Handl., Vol. 26, No. 6, pp. 1–12, Pls. 1–2.
66. ———, 1932. The copepods of the Woods Hole region, Massachusetts. U. S. Nat. Mus., Bull. 158, pp. I-XIX, 1–635, Pls. 1–41.
67. YAMAGUTI, S., 1939. Parasitic copepods from fishes of Japan. Pt 6, Lernaeopodoida, I. Vol. Jubil. pro Prof. S. Yoshida, Vol. 2, pp. 529–578, Pls. 34–58, Oosaka.

Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 2, No. 2, September 30, 1956.

ヒトエグサの海に於ける発生に就いて

(挿図第1図-3図; 図版 Plates XXI-XXII)

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On the Development of *Monostroma* in the Sea

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Résumé

In the central district of Mie Prefecture, Japan, *Monostroma* is cultivated by means of "Hibi" (setting-twigs, bamboo-twigs, nets made of palm-yarn, hemppalm-yarn) in the sea and used for food as "AONORI".

The life history of *Monostroma* has hitherto been studied by many phycologists and the configuration of early stage of development has also been clarified, but these were all done through indoor culture experiments and there has been no precise report yet which describes the natural configuration of early development of zoospores on "Hibi" in the sea. To "Hibi" in the sea, there attach not only the zoospores of HITOEGUSA (*Monostroma nitidum* WITTROCK?), but also those of HIROHANO-HITOEGUSA (*Monostroma latissimum* (KUETZ.) WITTROCK ?), AONORI (*Enteromorpha* spec.) and others together in mingled condition and, therefore, it is rather difficult to distinguish one from others in the early stage of development of zoospores. Under such circumstances, the writer observed these zoospores precisely, using rich materials collected from "Hibi" in the various cultural places of Mie Prefecture, to solve the difficult problem to the furthest possible degree. By this study the writer could distinguish these microscopic plants from each other to a considerable degree even in quite an early stage and gave some help to people concerned in attaching of the zoospores to "Hibi" which is done between September and October. Now the writer reports on HITOEGUSA and HIROHANO-HITOEGUSA only and expects to make a report on AONORI in the near future.

In HITOEGUSA, the zoospores develop and form small characteristic discs which afterwards perhaps upheave at the center. The cells in the central part of disc are rather dark in colour and round in shape, while these in the outer part are light and elongated. Such discs can only be seen in HITOEGUSA. Upheavals and early sporings before forming discs, however, have not been observed. It is the first time to observe such type of discs in the natural development of HITOEGUSA.

In HIROHANO-HITOEGUSA, the zoospores neither form such discs nor proceed so far as to form an upheaval. They develop and then always grow as a single layer. The natural development of zoospores were clearly followed by the writer as shown in accompanying plates. In addition, the natural cysts in the sea were observed for the first time in this district.

緒　　言

ヒトエグサ *Monostroma nitidum* WITTROCK (?) は緑藻類 *Chlorophyceae* のアオサ科 *Ulvaceae*, ヒトエグサ属 *Monostroma* に属する海藻で，体は一層の細胞より成り，極めて小なる根を以て他物に附着し，膜質葉状を呈し，柔軟にして縁辺は波縮し，往々裂片をなし，体の大きさは種々ありて 2.3～10～20 cm 以上にも達する。色は鮮緑色を呈し，光沢を有する美麗なる海藻で，主として本邦南部の沿岸 (伊勢湾，三河湾，東京湾，瀬戸内海沿岸等)，殊に外海に面する干潟線間の岩礁上，又は淡水の混入する内湾によく生育し，10 月初旬より幼体が出現し，12～2 月頃迄が最も繁茂する。この海藻は青海苔として用いられ，三重県の中勢地方にては殊に重要なる水産物である。抄製品又は佃煮材料として風味も良く，青海苔中の優品である。

ヒロハノヒトエグサ *Monostroma latissimum* (KUETZ.) WITTROCK (?) は新崎博士により，前記の種と区別されたものであるが，分類学上猶研究の余地もある。本種の葉体は大きく，縁辺 (稀に全面) 縮れ，色は黄緑色で淡く，老成すると小孔が多数出来，成育時期は主として 3 月から 5 月にかけてである。猶本種は前種に比して外洋に適する傾向がみられ，分布も広く，繁殖するので，前種に劣らず重要なる青海苔の一種である。俗に夏ダネ (早生) と称するのは前種であり，彼岸ダネ(晩生) と称しているのは之である。三重県松名瀬地方にて俗にギンアオと称するのは本種と思惟される。

毎年九月中下旬の種付け時期に到達すると，県下の多数の養殖業者が簇を持参し，これにヒトエグサの胞子が附着しているや否や鑑定を求められる。此の簇にはヒトエグサ，ヒロハノヒトエグサ，アオノリの胞子の他種々の微生物が附着し，鑑定上困難な場合が少くない。茲に筆者は之等を明確に区別せんとし，既に二年前より実際海に設置してある簇より游走子を採取精査した結果，漸く判明せる事が多い。勿論既に本邦藻類学者の室内培養により，その生活史がかなり闡明されているが，天然には相当複雑した形態をとる。本報告には秋嚢状体から放出される游走子が，肉眼で認められる小幼体に発展する迄の過程を明示し，種付けの参考に供した。猶アオノリについては後日報告する予定である。

観 察 と 考 察

(1) ヒ　ト　エ　グ　サ

秋嚢状体 cyst から放出される游走子が，簇に附着し，小幼体に発芽生育する過程において，このヒトエグサはヒロハノヒトエグサと全然異りたる経過をとる。即ち游走子が発芽生育して，特異な形状を示す盤状体を形成するに至ることである。此の盤状体は初期に於いて中心部には塊状をなせる四，五角形の大さ 4～4.5×4.5～3 μ 位の細胞が不規則に集合し，又周辺部には細長き細胞 (約 4×12 μ 位) が形成され，全体の大さ 36×42 μ 位の不規則な盤状体を呈す (第 1 図 A)。次に中心部と周囲の細胞が更に増加し，附図第 1 図の B にみる如きやや規則的な形状を示す盤状体となる (50×60 μ)。次になお更に多数の細胞が形成されて進展し，同図 C にみる如き特異な形状を示すに至る (130×135 μ)。周辺部の細胞は色が稍々淡くて細長くのび，体は一層の細胞から成り，中央部が膨出して袋状となり，上部が裂開して後一層になると思惟される。

斯くの如き盤状体は室内培養に於いて山田，神田氏 (1941) が *Monostroma zostericola* TILDEN に於いて，又山田，斎藤氏 (1938) が *Monostroma angicava* KJELLM. に於いても夫々観察しているが，新崎氏 (1946) の伊勢三河地方で産するヒトエグサに於いては図示されていない。同氏の報告より判断すれば，游走子から発達した発生体の形状は，Bliding (1935) が *Monostroma wittrockii* BORN. に於いて観察した発生体(二本の繊毛を持つた雌性配偶子様の游走胞子 swarm-spore から接合なくして発芽，発生したもの) に類似し，体は二層の細胞より成り，袋状に発達するようである。この点については，猶今後研究の余地があろう。

実際海に於ける簇には，上述の如き盤状体は単独に生ずることは少く，Pl. XXI の 4 に示せる如く，縁辺の細長くのびた細胞が互に長くのびていり込み合い，密集する事が多い。猶この盤状体の発生過程及び袋状体に就いては，完全には観察し得なかつた点もある。

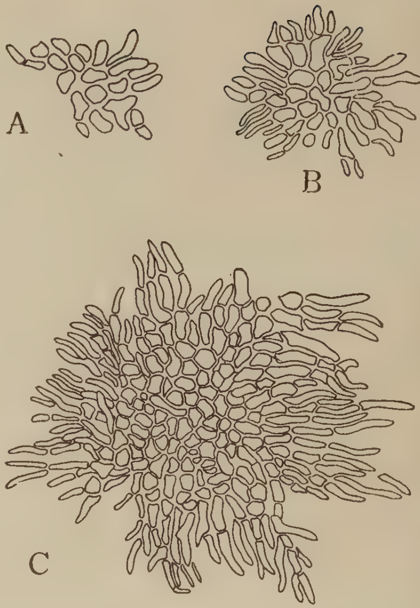


図 1　ヒトエグサ *Monostroma nitidum* WITTROCK(?) の盤状体
A.　初期の盤状体　×ca. 400
B. C.　更に順次発達せる盤状体　×ca. 400
(三重県松名瀬にて 1955 年 11 月 2 日採集)

(2) ヒロハノヒトエグサ

春成熟した葉体から放出された配偶子が，接合して接合子となり，夏に至り之が嚢状体 cyst を形成する事は既に岡枝博士及び他の藻類学者の室内培養により観察されているが，三重県下の養殖場に於いて，天然の海に於ける簇に之が存在する事が，筆者に依り初めて確認された(第 2 図及び Pl. XXII の 1)。この天然に存在する嚢状体は，ほぼ円型を呈し，径 15×15 μ ありて外囲は寒天質様のものにて包囲され，全体としては径 18×18 μ 位なり。実際の簇には単独にて存在する事もあるが，屢々数個乃至多数集団的に附着する。之等の嚢状体の一方が開口し，中の細胞は游走子として放出され (第 2 図の B)，空虚なるものの存在する事も観察した(第 2 図の C)。大きさは開口せるもの 18×21μ 位，空虚なるもの18×23μ 位なり。この嚢状体より放出せる游走子は，やがて 2 分割せんとし，洋梨状をなし，4×10 μ 位あり (第 3 図の A)。次に同図 B に示す如く明かに 2 分割し，6×18 μ あり。更に進展して数細胞に分割し，大きさ 13×30 μ 位に達し，先

図 2　ヒロハノヒトエグサ *Monostroma latissimum* (KUETZ.) WITTROCK (?) の嚢状体
A.　游走子の充実せるもの　×ca. 400
B.　開口部を有するもの　×ca. 400
C.　空虚なるもの　×ca. 400
(三重県内瀬にて 1955 年 10 月 25 日採集)

端の細胞は 2 個横に長くのびて配列するも，次位のものは縦長に 2 個並び，基部の細胞 (6×12 μ) は細長くのび，頂部截形なるも末端は尖りて礁に附着す。次に更に発達して細長き発芽体 (9×54 μ) となり，頂部の 2 細胞はやはり横に長く並ぶも，以下の細胞は不規則な形状をなし，10 数個に分割し，基部の 2〜3 細胞は長くのびて末端細く尖り，根様糸の初期を形成するに至る (第 3 図 D)。更に進展して図 E に示す如く多数の細胞を持つに至り，巾広くのび，基部の 2〜3 細胞は大きく，最終部の細胞は極めて細長くのびて顕著なる根様糸となり，全体の大きさ 36×90 μ に達する。猶更に伸長せるものは同図 F に示す如き小葉状体を呈するに至り，基部の 10 余個の細胞は細長くのび，完全なる根様糸をなして他物に附着する。大きさは 75×225 μ 位あり。更に発達して Pl. XXII の 8 に示すごとく，全円なる楕円体の小幼体 (大きさ 720×885 μ) となるものあり，又は上部の縁辺に不規則なる裂片を有する小幼体となるものもありて，肉眼にて観察し得るに至る。

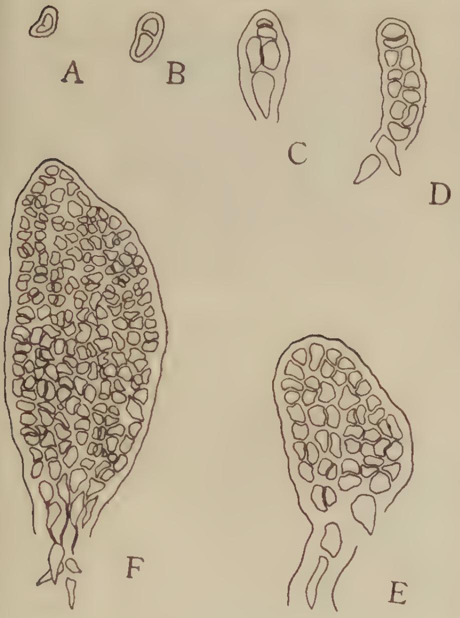


図 3　ヒロハノヒトエグサ *Monostroma latissimum* (KUETZ.) WITTROCK(?) の発芽体
A.　二分割せんとする游走子　×ca. 400
B.　二細胞の発芽体　×ca. 400
C.　数細胞の発芽体　×ca. 400
D.　十数個の細胞を持つ発芽体　×ca. 400
E.　更に発達せるもの　×ca. 400
F.　小幼体　×ca. 250
(三重県内瀬にて 1955 年 10 月 25 日採集)

ヒロハノヒトエグサの発芽体及び発生体は，上述の如き経過をとり，常に一層の細胞より成り，ヒトエグサの如き盤状体をとることはない。游走子から小幼体に至るまで多数の材料を精査した結果，漸くにして上述の如く順次確認した。

摘　　要

三重県下に於いて秋，天然の海に於ける礁に附着せるヒトエグサ，ヒロハノヒトエグサ，アオノリの游走子が発芽進展して，肉眼で認め得る小幼体に至るまでの過程を詳しく観察し，夫々之等を区別し得た。(アオノリは後日報告する予定)

ヒトエグサの場合は，本観察に於いて此の過程中に於いて特徴ある盤状体 (第 1 図，Pl. XXI) を形成するのを確認した。此の盤状体の中心部が膨出して袋状となり，後上部裂開して一層の細胞より成る葉状体を形成すると思惟せられる。然し此の盤状体の発生過程及び袋状体に就いては，観察し得なかつた点もあるので多少の疑点も存する。

ヒロハノヒトエグサに於ては，最初より常に一層の細胞より成り，第 3 図及び Pl. XXII の 2〜8 に示す如き形態を以て発芽進展する事を明確に追求し得た。猶天然の海に存する嚢状体 (第 2 図，Pl. XXII の 1) が此の地方に於いて初めて観察された。

文 献

新崎盛敏，アヲサ科及びヒトエグサ科植物の胞子の発芽について，1946（生物 1，5-6).
————，青海苔，1946（水産食糧増産叢書 2).
，伊勢三河湾産ヒトエグサに就いて，1949（日水会誌 15，3).
Bliding, Sexualität und Entwicklung Bei Einigen Marinen Chlorophyceen, 1935 (Svensk Botanisk Tidskrift).
Fritsch, The Structure and Reproduction of the Algae, Vol. 1, 1935.
Kunieda, On the life-history of *Monostroma*, 1934 (Proc. Imp. Acad., 10, 2).
Miyake and Kunieda, On the conjugation of the Gametes and the Development of the Zoospores in *Ulvaceae*, 1931 (Journ. Coll. Agri. Vol. XI, No. 3).
瀬木紀男，ヒトエグサの「腐れ」に就いて，1953（藻類 Vol. 1, No. 2).
瀬木紀男，後藤和四郎，ヒロハノヒトエグサの游走胞子に就いて，1955（藻類 Vol. 3, No. 1).
Suneson, Notes on the life-history of *Monostroma*, 1947 (Svensk Botanisk Tidskrift, Bd. 41, H. 2).
時田 郇，緑藻アヲサ科植物の生活史に関する研究，1938（植物及動物第7巻第7号).
Yamada and Saito, On some culture experiments with the swarmers of certain species belonging to the *Ulvaceae*, 1938 (Sci. Pap. Inst. Alg. Res. Fac. Sci. Hokkaido Imp. Univ., Vol. 11, No. 1).
Yamada and Kanda, On the culture experiment of *Monostroma Zostericola* and *Enteromorpha nana* var. *minima*, 1941 (Sci. Pap. Ins. Alg. Res. Fac. Sci. Hokkaido Imp. Univ., Vol. 11, No. 2).

□ □ □

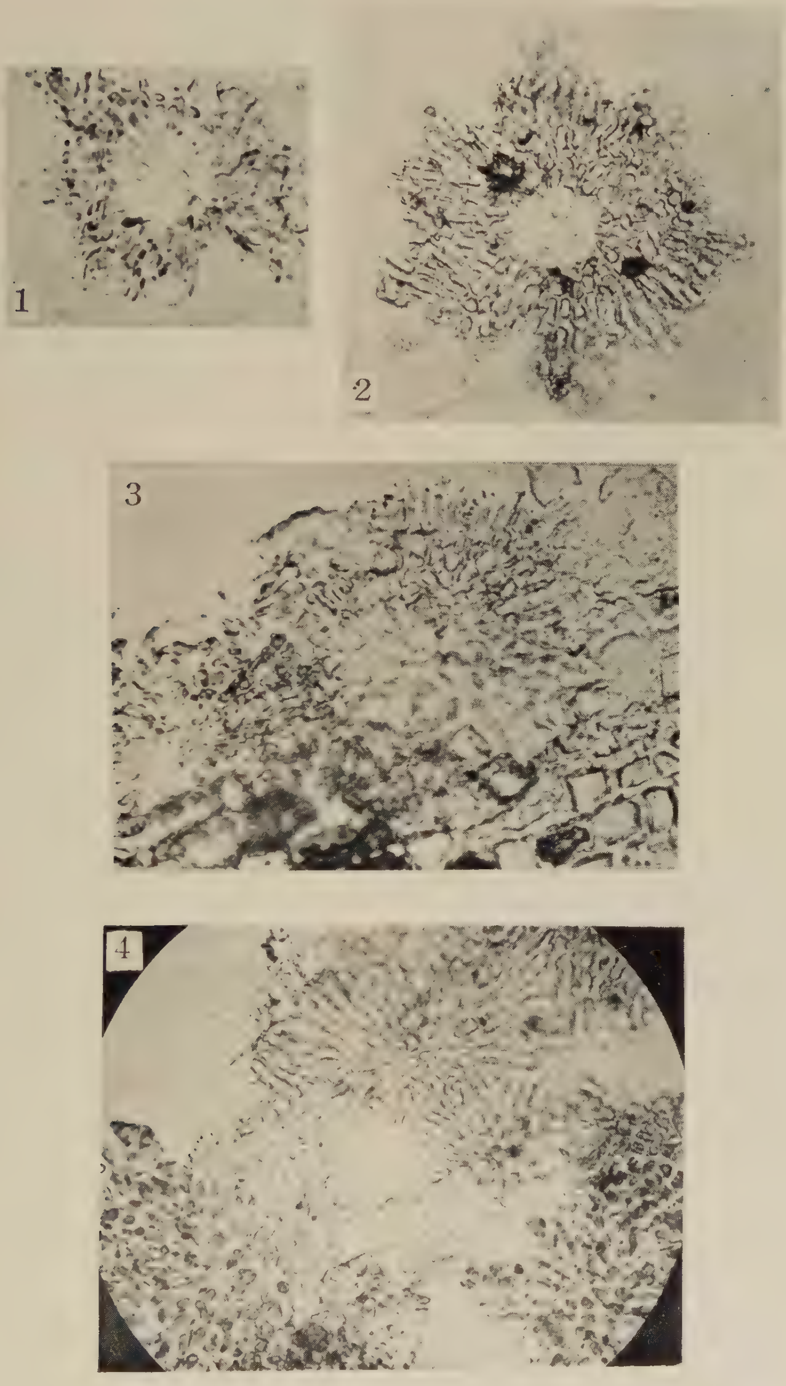
Explanation of the Plate XXI

Plate XXI. ヒトエグサ *Monostroma nitidum* WITTROCK (?) の盤状体

1. 初期の盤状体 ×ca. 600
2. 更に進展せる盤状体 ×ca. 400
3. 簇上に附着せる盤状体 ×ca. 500
4. 数個集合せる盤状体 ×ca. 500

（三重県松名瀬にて 1955年11月2日採集）

PLATE XXI



Explanation of the Plate XXII

Plate XXII. ヒロハノヒトエグサ *Monostroma latissimum* (KUETZ.) WITTROCK (?) の発芽体

1. 嚢状体　×ca. 1000
2. 分割せんとする游走子　×ca. 500
3. 数細胞の発芽体　×ca. 700
4. 十数個の細胞よりなる発芽体　×ca. 500
5. 6. 7. 更に順次発達せるもの　×ca. 500, ×ca. 400, ×ca. 420
8. 小幼体　×ca. 75

(三重県内瀬にて 1955 年 10 月 25 日採集)

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Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 2, No. 2, September 30, 1956.

養 鰻 池 の 水 変 り に 関 す る 研 究

III. 水変り池の Brachionus plicatilis に対する晒粉・硫酸銅・消石灰・海水並に淡水の致死濃度

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Studies on the "Mizukawari" in Eel-culture Ponds.

III. The Effects of Chlorinated lime, Cupper Sulphate, Calcium Hydroxyde, Sea- and Fresh-waters upon Brachionus plicatilis in the "Mizukawari" Pond

(*With 5 Tables*)

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Résumé

This experiment was carried out to get the fundamental materials for the control to the abnormal reproduction of the rotifer, that is the very cause of the "summer kill", so-called "Mizukawari" in Japan, in eel-culture ponds.

For the materials of the experiment, the "Mizukawari" water of the natural eel-culture pond and those *Brachionus plicatilis* O. F. MÜLLER belonging to the brackish-water rotifer abnormally reproduced there, were used.

The lethal concentrations of chlorinated lime, cupper sulphate, calcium hydroxyde, and sea- and fresh-waters for *Br. plicatilis* are as shown below:

Reagents	Lethal limits		
Chlorinated lime	0.75–1.0	p.p.m.	as the available Cl
Cupper sulphate	2–4	p.p.m.	as $CuSO_4 \cdot 5H_2O$
Calcium hydroxyde	200	p.p.m.	as $Ca(OH)_2$
Sea- and fresh-waters	10‰	(high)	as Cl
(chlorinity)	0.5–1.0‰	(low)	〃

Of these, chlorinated lime is the most suitable for the practical use.

養鰻池の水変り時に異常増殖をする輪虫類の撲滅法に関しては，稲葉 (1937) が *Brachionus calyciflorus*, *Br. urceolaris* に対する海水の致死塩分濃度の実験を行い，両種は Cl 5‰ で殆んど斃死することを報告した例を知るのみである。本研究は養鰻池に異常増殖をし且つ水変りの 1 因をなす輪虫類の薬剤による control に関する基礎資料を得る目的で，昭和 30 年 5 月から 10 月に亘り，津市江戸橋一帯の養鰻池に大増殖をし，ウナギその他の養殖魚に相当の被害を与えた水変り[1] の原因をなしたと考えられる輪虫類，*Brachionus plicatilis* に対する漂白粉，硫酸銅，消石灰，海水並に淡水の致死濃度を実際の水変り池水を用いて明かにすることが出来たので，その結果を報告する。

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1) 詳細は別報で報告する予定である。

プランクトンの薬剤処理について有益な助言を与えられた東京都水道局小島貞男技師に謝意を表すると共に，研究上種々の便宜をあたえられた三重県淡水養殖協同組合長加藤慎太郎氏に感謝します。なお本研究に種々の助言をあたえられた本学水産学部長岡田弥一郎教授に謝意を表します。

材料並に方法

本研究に使用した *Brachionus plicatilis* 並に池水は津市栗真町屋町加藤慎太郎氏所有の養鰻池（第2号池）の水変り中のものである。この池は昭和30年6月6日から水変りとなり，池水は緑色から暗緑色を経て，6月8日には暗赤褐色となり，ウナギ・ボラの1部は斃死し，殆んど全部鼻上げをした。池の風下の表面には ***Br. plicatilis*** による“赤潮”[2)] が形成され，表層水 100 cc 中の沈澱量は 3.15 cc であつた。

この実験に供した輪虫の材料及び池水は6月9日に採取した。このときの池の環境条件は，W.T. 24.9°C；透明度 38 cm；水色 暗赤褐色；pH 7.3；溶存酸素 0.40 cc/L (6.9%)；Cl 5.512 g/L；B. C. P. Alkalinity 2.460 milliequiv./L；$KMnO_4$ 消費量 63.6 mg/L（不沪過水）であつた。この水変り池におけるプランクトン相と個体数密度は，*Brachionus plicatilis* 98, *Br. quadridentatus* 10, *Br. urceolaris* 5, *Keratella cruciformis* var. *eichwaldi* 5, *Br. calyciflorus* 1, 計 119 個体/5 cc で，植物性プランクトンは殆んど見られず，動物性プランクトンは全部輪虫類より成り，その中では *Br. plicatilis* が圧倒的で，全体の 82% を占めていた。

この池水の中にプランクトン・ネットで集めて濃縮し実験室に持ちかえり，直ちに大型水槽に移し，2時間放置し，器底に沈降したものは入らないよう中層からサイフォンで静かに 200 cc 容量の三角フラスコに約 100 cc とり実験に供した。各瓶中の *plicatilis* の個体数密度は平均 1250 個体/cc であつた。各瓶に別に正確に調製した漂白粉・硫酸銅・消石灰の水溶液を夫々所定の濃度になるように加えて全体を 100 cc にした。海水並に淡水の影響決定の方法は後述する。

薬剤並に海水，淡水の影響による *Br. plicatilis* の生死の判定には2つの方法を併用した。第1は主として肉眼により浮游沈降，運動状況を綜合して推定し，第2に注加後1, 4, 24時間後に各瓶の中層から静かに 2 cc を駒込ピペットでとり，フォルマリンを加えて固定し，実験終了後遠心分離器にかけて沈澱させ，計数盤を用いて顕微鏡下で計数し生存率を計算した。しかしこの場合のサンプリングは，*Br. plicatilis* の顕著な正の走光性により窓側の器壁に密集する傾向があつたので充分精密に行うことは困難であつた。

実験結果

1. 漂白粉

一級化学薬品，有効塩素量 24.08%（本実験の直前に検定した）の漂白粉を用い，有効塩素量 0.5〜50 p.p.m. に亘り8種の濃度にした (Table 1)。各濃度における *Br. plicatilis* の浮游沈降並に生死，生存率の状況は Table 1 に示した。

Table 1 に明かのように，*Br. plicatilis* は有効塩素量 5 p.p.m. 以上 50 p.p.m. まで

2) *Br. plicatilis* は普通は殆んど無色透明に近いが，消化管は赤褐色に着色し，その集合体も赤褐色を呈していた。

の晒粉の濃度では，注加直後粘液にからまつて器底に沈降し斃死した。2.5 p.p.m. では，注加直後から 4 時間後までは生きて動いているのは認められなかつたが，24 時間後には極く 1 部 (0.2%) が器底近くで明かに動いているのが認められた。1.0 並に 0.75 p.p.m. の濃度では大部分が沈降斃死するが，1 部生存し浮游するものもあり，生存率は夫々平均

Table 1. The effects of various concentrations of chlorinated lime upon *Brachionus plicatilis* in "Mizukawari" water.
+ stands for the distribution throughout all strata;
−, the settlement on the bottom.
Water temperature ranged from 25.2°C to 26.7°C.

Bottle Number	Concentration available Cl	After 10 minutes	After 1 hour	After 4 hours	After 24 hours	Survival rate after 24 hours (%)
1	50 p.p.m	−−−	−−−	−−−	−−−	0
2	20	−−−	−−−	−−−	−−−	0
3	10	−−−	−−−	−−−	−−−	0
4	7.5	−−−	−−−	−−−	−−−	0
5	5.0	−−−	−−−	−−−	−−−	0
6	2.5	−−−	−−−	−−−	−∓−	0.2
7	1.0	−+−	−+−	−+−	−+−	10
8	0.75	−+−	−+−	−+−	−+−	15
9	0.50	++−	++−	++−	++−	65
10	control	+++	+++	+++	+++	100

Table 2. The effects of Cupper Sulphate upon *Br. plicatilis* in the "Mizukawari" water.
+ stands for the distribution throughout all strata;
−, the deposition on the bottom.
Water temperature ranged from 23.0°C to 26.7°C.

Bottle Number	Concentration $CuSO_4 \cdot 5H_2O$	After 10 minutes	After 1 hour	After 4 hours	After 24 hours	Survival rate after 24 hours (%)
11	800 p.p.m.	−−−	−−−	−−−	−−−	0
12	600	−−−	−−−	−−−	−−−	0
13	400	−−−	−−−	−−−	−−−	0
14	200	−−−	−−−	−−−	−−−	0
15	100	−−+	−∓−	−∓-	−−−	0
16	40	−−+	−−+	−∓−	−∓−	0.05
17	20	±	±	−∓−	−∓−	0.2
18	4	++−	++−	+−−	+−−	1
19	2	++−	++−	+±+	+±+	72
20	0.4	+++	+++	+++	+++	100
21	0.2	+++	+++	+++	+++	100
22	0.04	+++	+++	+++	+++	100
23	0.02	+++	+++	+++	+++	100
24	control	+++	+++	+++	+++	100

10%, 15% であつた。0.5 p.p.m. では 1 部斃死するが生存率は 65% で大半が生き残る。

要するに水変り池の *Brachionus plicatilis* に対する漂白粉の致死濃度は有効塩素量として 0.75～1.0 p.p.m. にあるといえよう。且つ漂白粉の効果は極めて顕著でしかも速効的である。

2. 硫 酸 銅

化学薬品 $CuSO_4 \cdot 5H_2O$ を用い，40 p.p.m. 並に 8000 p.p.m. の 2 種の $CuSO_4 \cdot 5H_2O$ の水溶液を原液として，0.02 p.p.m.～800 p.p.m. に亘り，13 種の濃度について *Br. plicatilis* に対する影響を観察した。(Table 2)。

Table 2 に示されているように，*Br. plicatilis* は 100 p.p.m. 以上 800 p.p.m. ($CuSO_4 \cdot 5H_2O$ として) までの濃度では，注加直後全個体が白色塊状になつて器底に沈澱し斃死した。4, 20, 40, 100 p.p.m. では時間の進行と共に生存個体は減少し，24 時間後には 100 p.p.m. では全部斃死し，40 並に 20 p.p.m. では極く 1 部 (夫々生存率は 0.05%, 0.2%) が生き残つた。4 p.p.m. では注加直後には 38%, 4 時間後には 5%, 24 時間後には 1%, の生存率を示し，時間と共に生存率は低下する。2 p.p.m. の濃度の 24 時間後の生存率は 72% で，0.4 p.p.m. 以下の濃度では影響は認められなかつた。

従つて *Br. plicatilis* に対する $CuSO_4 \cdot 5H_2O$ の致死濃度は 2～4 p.p.m. にあり，効果は漂白粉に比べると遅効性であるといえよう。

3. 消 石 灰

化学薬品 (特級) の水酸化カルシウムを使用した。2 p.p.m.～400 p.p.m. に亘り 13 種の濃度にした。その結果は Table 3 はに示した。

Table 3. The effects of Calcium hydroxyde on *Brachionus plicatilis* in the "Mizukawari" water.
+ stands for the swimming throughout all strata;
−, the deposition on the bottom.
Water temperature ranged from 24.0°C to 26.7°C.

Bottle Number	Concentration $Ca(OH)_2$	*Brachionus plicatilis* After 10 minutes	1 hour	4 hours	24 hours	Survival rate after 24 hours (%)	pH of the water	24 hours
25	400 p.p.m.	− − −	− − −	− − −	− ∓ −	0.1	>9.8	9.6
26	300	− ∓ −	− ∓ −	− ∓ −	− ∓ −	1	>9.8	9.4
27	200	±	±	±	±	43	>9.8	8.8
28	100	+ ± +	+ ± +	+ ± +	+ ± +	72	9.5	8.3
29	80	+ ± +	+ ± +	+ ± +	+ ± +	89	9.4	8.2
30	60	+ + +	+ + +	+ + +	+ + +	100	9.2	7.7
31	40	+ + +	+ + +	+ + +	+ + +	〃	8.9	7.5
32	20	+ + +	+ + +	+ + +	+ + +	〃	8.1	7.4
33	10	+ + +	+ + +	+ + +	+ + +	〃	7.7	7.4
34	8	+ + +	+ + +	+ + +	+ + +	〃	7.6	7.4
35	6	+ + +	+ + +	+ + +	+ + +	〃	7.4	7.4
36	4	+ + +	+ + +	+ + +	+ + +	〃	7.4	7.3
37	2	+ + +	+ + +	+ + +	+ + +	〃	7.3	7.3
38	control	+ + +	+ + +	+ + +	+ + +	〃	7.2	7.3

Table 3 に明かのように，300 並に 400 p.p.m. ($Ca(OH)_2$ として) は注加直後輪虫類は粘液を分泌し全体がそれにからまるようにして器底に沈降し，殆んど大部分の個体が斃死した。しかし 24 時間後には 400 p.p.m. の濃度でもその極く 1 部 (0.1%) が生存し運動しているのが認められた。このときの pH は 9.6 に低下していた。300 p.p.m. では生存率は 1% で殆んど斃死したと見てよい。200，100，80 p.p.m. と濃度が低下するにつれて生存率は 43%，72%，89% と増加し，60 p.p.m. 以下の濃度では全く影響は認められなかつた。

消石灰の致死作用はその強いアルカリ性に依存すると考えられているが，400，300，200 p.p.m. の濃度では注加直後には pH いずれも 9.8 以上を示し，100 p.p.m. は pH=9.5 を示した。しかし 24 時間後に pH は著しく低下し，夫々 9.6，9.4，8.8，8.3 になっていた。植物性プランクトンが繁殖し緑色を呈する養鰻池においては，晴天の日中には，顕著な炭酸同化作用によつて pH は最高 9.7 位まで上昇することがあるが，*Br. plicatilis* はそれ以上の pH でないと致死作用の見られないことは甚だ興味深い。

要するに，消石灰の致死作用は，漂白粉，硫酸銅，海水並に淡水に比して顕著ではない。その致死濃度は $Ca(OH)_2$ として 200 p.p.m. pH の点からは 9.8 以上と見てよかろう。

Table 4. The effects of Sea- and Fresh-waters upon the brackish-water rotifer, *Brachionus plicatilis* in the "Mizukawari" water.
+ stands for the swimming throughout all strata;
−, the settlement on the bottom.
Water temperature ranged from 24.3°C to 25.1°C.

Bottle Number	Concentration Cl ‰	After 10 minutes	1 hour	4 hours	24 hours	Survival rate after 24 hours (%)
39	Sea-water (19.32)	−−−	−−−	−−−	−−−	0
40	17	−−−	−−−	−−−	−−−	0
41	15	−−−	−−−	−−−	−−−	0
42	13	−−−	−−−	−−−	−−−	0
43	11	−−−	−∓−	−∓−	−∓−	10
44	9	+++	+++	+++	+++	100
45	7	+++	+++	+++	+++	100
46	5	+++	+++	+++	+++	100
47	3	+++	+++	+++	+++	100
48	1	++−	++−	++−	++−	90
49	0.5	−∓−	−∓−	−∓−	−∓−	10
50	0.1	−−−	−−−	−−−	−−−	0
51	Fresh-water	−−−	−−−	−−−	−−−	0
52	Control (5.512)	+++	+++	+++	+++	100

4. 海水並に淡水

Brachionus plicatilis に対する塩分濃度の致死限界の決定には，水変りした前記養鰻池の池水 (Cl=5.512‰) に海水 (Cl=19.32‰) 並に三重県立大学水産学部構内の井戸水 (淡水) を加えて塩素量 0 (淡水) から 19.32‰ (海水) に亘り，13 種の濃度を使用した。

Cl 7‰ 以上の濃度は海水と池水，Cl 5% 以下の濃度は池水と井戸水を夫々混合して三角フラスコに各々 100 cc を作つた。各フラスコに前記の水変り池水を 1 cc（その中に約600 個体の *Br. plicatilis* を含む）を加えた[3]。

Table 4 に明かのように，塩分濃度の影響は極めて顕著であり，*Br. plicatilis* の致死塩分限界は明かに高鹹部と低鹹部の 2 ケ所に存在する。即ち *Br. plicatilis* は Cl 11‰ 以上，13‰，15‰，17‰，19.32‰（海水）の高鹹濃度と，Cl 0.5‰ 以下，0.1‰，淡水の低鹹濃度では投入後間もなく全個体が器底に沈降し，各個体がばらばらに白色に変つて斃死した。しかし Cl 1‰ では幾分弱り，大部分の個体が器底に沈降したが斃死することはなく器底上を匍匐するか，1 部は器底近くの水中に浮游していた。Cl 0.5‰ では殆んど大部分沈降したが，その中の約半数は不活潑ながら僅かに微動し生存していることを示し，極く 1 部分は器底近くの水中にあつた。

1 方 Cl 9‰，7‰，5‰，3‰ では Control（養鰻池水，Cl=5.512‰）におけると同様に，体は殆んど無色で白変することなく活潑に水中を游泳していた。

従つて *Br. plicatilis* に対する塩分の致死限界は明かに高鹹部と低鹹部の 2 ケ所に存在し，前者の致死限界は 9‰ と 11‰との間，即ち 10‰ に，後者の限界は 0.5‰ と 1‰ との間にあると思われる。

考　　察

水変り養鰻池に大増殖をした輪虫類の *Brachionus plicatilis* に対する漂白粉，硫酸銅，消石灰，海水並に淡水の致死濃度の本実験の結果は Table 5 に要約出来る。

Table 5. The lethal limits of some reagents to *Brachionus plicatilis* in the "Mizukawari" pond.

Reagents	Lethal limits	
Chlorinated lime	0.75～1.0 p.p.m.	As the available Cl
Cupper sulphate ($CuSO_4$)	2～4 p.p.m.	As $CuSO_4 \cdot 5H_2O$
Calcium hydroxyde ($Ca(OH)_2$)	200 p.p.m.	As $Ca(OH)_2$
Sea- and Fresh-waters	10‰ (high)	As Cl
(Chlorinity)	0.5～1.0‰ (low)	〃

稲葉 (1937) は静岡県浜名湖地方の養鰻池の水変り時に大発生をする輪虫類，*Br. calyciflorus*, *Br. urceolaris* に対する海水の致死効果の実験を行い，Cl 5‰ に致死限界の存在することを見ている。伊藤 (1955, 未発表) は三重県の 239 面の養鰻池におけるプランクトン動物の分布と池水の塩分との関係を明かにし，淡水系の輪虫類，*Br. calyciflorus* 並に *Br. urceolaris* は夫々 Cl 4.058‰ 以下，Cl 6.992‰ 以下の水域に分布し，代表的汽水性輪虫類に属する本実験に使用した *Br. plicatilis* は Cl 0.664～7.248‰ の所謂汽水域にのみに分布することを報告し，且つ水変り時には高鹹池（Cl 2～7‰）では *Br. plicatilis*，低鹹池（Cl 0.2～3‰）においては *Br. calyciflorus* が夫々異常増殖をす

3) そのために各フラスコの塩素含有量はいく分変化するが，その変化は最大 50 mg 程度であり，極めて小さいので，その影響はこの実験では顧慮しなかつた。

る場合の多いことを見ている。従つて上述の稲葉の *Br. calyciflorus* 並に *Br. urceolaris* に対する塩分の致死限界は天然の養鰻池における両種の棲息塩分限界と略々一致する。なお本実験における *Br. plicatilis* に対する塩分の致死限界は三重県養鰻池における本種の棲息塩分限界と極めてよく一致している点は注目すべきであろう。

其の他に水変り養鰻池の輪虫類の薬剤による撲滅実験の例を知らない。薬剤によるプランクトンの control は上水道方面では盛んに利用され，特に貯水池におけるプランクトン藻類の control に晒粉，硫酸銅等が用いられている。(酒井・山地；1930，酒井，1930；酒井・吉崎，1933；小島，1954；Hale, F. E., 1954；International Water Supply Assoc., 1952)。小島（筆者宛の私信）によると，貯水池における淡水産輪虫類に対する晒粉の致死濃度は 1.0 p.p.m.（有効塩素として），硫酸銅の致死濃度は 2.0 p.p.m.（$CuSO_4\,5H_2O$ として）程度であり，且つ動物性プランクトンは晒粉に弱く，硫酸銅に対しては強い，しかし植物性プランクトンはその逆であるという。筆者の *Br. plicatilis* に対する晒粉並に硫酸銅の致死濃度の結果は小島の淡水産輪虫類に対する結果とよく一致するのは興味深い。

中井・小海 (1931) によると，イカリムシの卵及び幼虫は晒粉 1 p.p.m. (1/100 万，有効塩素量として) 以上で 3 日以内に死滅し，一方寄主としてのウナギ，コイに対する致死濃度は 5～6.7 p.p.m. (1/20 万～1/10 万) であるという。従つてこのイカリムシの卵及び幼虫の致死濃度は輪虫類，*Br. plicatilis* のそれに略々一致する。菅原 (1955) によると淡水産浮游性緑藻類の *Scenedesmus* の増殖に対する銅 (Cu) の抑制限界濃度は 0.0125 p.p.m. (Cu として) であるという。

水変り養鰻池に異常増殖をした輪虫類の薬剤による control にあたつては，輪虫類のみに効果的で，養殖魚は勿論養鰻池における水中酸素の供給源である植物性プランクトンの生存とその増殖になるべく影響を与えない薬剤を選択することは言うまでもない[1)]。本実験に用いた上記の 3 種の薬剤中でこの条件を満足させ，且つ効果的なものは漂白粉 (晒粉) である。輪虫類に対する漂白粉の効果は速効的であり，且つその使用並に取扱いはイカリムシの駆除を通して業者はよく習得している。イカリムシの撲滅のための漂白粉の施用で養鰻池の植物性プランクトンも死滅する（大島，1931）が，業者によるとその散布後には極めて良好な植物性プランクトンの増殖がおこり，また輪虫類に対する致死濃度はウナギ，コイのそれより小さく，約 1/6 であるから，水変り時に異常増殖をし且つ水変りの原因をなすと考えられる輪虫類，*Br. plicatilis*, *Br. calyciflorus* の撲滅には漂白粉の施用が適当であろう。海水並に淡水も *Br. plicatilis* の control に対し極めて効果的である，しかしその致死塩分濃度 Cl 10‰ 以上，並に Cl 0.5‰ 以下にすることは，養鰻池の立地条件から見て実際的には不可能であろう。

また本実験には実際の水変り池水とその中に大増殖をした輪虫類を使用したので，前述の致死濃度は水変り池にそのまま適用出来る。なお水変り養鰻池においては，日射の強い晴天には底層に，曇天並に雨天には表層に *Br. plicatilis* は密集して分布する(伊藤・岩井，1956)，従つて晒粉の使用は曇天で波立たない日を選んだ方がより効果的であろう。

1) 各種農薬の養鰻池の輪虫類並に植物性プランクトンに対する影響については別報で報告する。

摘　要

1) 本実験は養鰻池の水変り時に異常増殖をし，且つ水変りの 1 因をなすと思われる輪虫類，*Brachionus plicatilis* に対する漂白粉，硫酸銅，消石灰，海水並に淡水の致死濃度を明かにするために行つた。実験には実際の水変り池水とその輪虫類を使用した。

2) 漂白粉の効果は顕著で且つ速効的である。致死濃度は 0.75〜1.0 p.p.m.（有効塩素量として）である。

3) 硫酸銅の効果は遅効的であり，致死限界濃度は $CuSO_4 \cdot 5H_2O$ として 2〜4 p.p.m. である。

4) 消石灰の効果は顕著でない。致死濃度は 200 p.p.m.（$Ca(OH)_2$ として）で，pH の点からは 9.8 以上である。

5) 海水並に淡水の注入による汽水性輪虫類，*Br. plicatilis* に対する致死塩分濃度は Cl 10‰ 以上の高鹹部と Cl 0.5‰ 以下の低鹹部の 2 ケ所にある。この致死塩分濃度は天然の養鰻池における本種の棲息塩分限界とよく一致する。

6) これらの薬剤の中で，実際の養鰻池の水変りにおける輪虫類の control に対しては，其の効果，取扱い，植物性プランクトンに対する影響の点から見て，漂白粉（晒粉）の適用が最も適当であろう。その施用は曇天で静穏な日に行えばより効果的であらう。

文　献

HALE, F. E., (1954). The Use of Copper Sulphate in control of Microscopic Organisms. 43 pp.

稲葉　峻 (1937). 養鰻池の水変りに関する予察的研究，魚介類斃死原因調査報告，第 II 報，静岡県水産試験場浜名湖分場，pp. 39.

伊藤　隆 (1955). 三重県養鰻池における水質とプランクトンとの関係，鰻のシンポジウム，p. 19〜30．日本水産学会中部支部．

——— (1955). 養鰻池の水変りに関する研究． I. Brachionus plicatilis（輪虫類）によるプランクトン植物の捕食作用（水変りの 1 因として）．Report of Faculty of Fisheries, Prefectural University of Mie, Vol. 2, No. 1, p. 162–167.

——— (1955). 養鰻池の水変りに関する研究． II. Brachionus plicatilis による水変りにおける pH, O_2 の変化． Report of Faculty of Fisheries, Prefectural University of Mie, Vol. 2, No. 1, p. 168–177.

———． 三重県養鰻池の陸水学的研究． I. 池水の塩素含有量とプランクトン動物相（未発表）.

伊藤　隆・岩井寿夫 (1956). 養鰻池の水変りに関する研究． IV. 水変り池における Brachionus plicatils の垂直分布． Ibid. Vol. 2, No. 2, p. 325〜334.

International Water Supply Association (1952). The Effects of Algae in Waters Supplies. 2nd Congress Question 7. pp. 82.

小島貞男 (1954). 薬品処理記録から見た貯水池藻類の生態．水道協会雑誌，No. 237, p. 20〜26.

中井信隆・小海英松 (1931). イカリムシの生物学的研究．水産試験場報告，No. 2, p. 93〜121.

大島信夫 (1931). 養魚池の異常水質に就いての 2，3 の知見．水産研究誌，Vol. 26, No. 7, p. 228〜230.

酒井　儼 (1930). 硫酸銅による珪藻撲滅に関する試験． 応用動物学雑誌，Vol. 2, No. 2, p.96〜103.

酒井　儼・山地　尚 (1930). 東京市上水道村山貯水池に発生せるペリヂニウムの漂白粉による影響に就いて．水産研究誌，Vol. 25, No. 10, p. 262〜265.

酒井　儼・古幡一夫 (1933). 薬品による珪藻の処理試験．東京市衛生試験所報告，9, p. 44〜52.

菅原　健 (1955). 私が近年に関係した水質汚濁の研究について． 日本陸水学会大会特別講演（5 月 28 日，彦根）.

Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 2, No. 2, September 30, 1956.

養鰻池の水変りに関する研究

IV. 水変り池における Brachionus plicatilis の垂直分布

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Studies on the "Mizukawari" in Eel-culture Ponds.

IV. The Vertical Distributions of Brachionus plicatilis in "Mizukawari" Ponds.

(*With 2 figures and 5 tables*)

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Résumé

1) The vertical distribution of *Brachionus plicatilis* O. F. MÜLLER was investigated in four "Mizukawari" eel-culture ponds in Tsu City, Mie Prefecture, middle Japan, and brief experiments were made to determine the phototaxis and geotaxis of *Br. plicatilis* in the laboratory.

2) *Br. plicatilis* shows a negative phototaxis to the strong light, and a positive phototaxis to the weak one. On the other hand it shows a negative geotaxis in the dark, but no reaction in the diffuse light.

3) In the strong sunbeams in the daytime, in the limpid "Mizukawari" eel-culture ponds *Br. plicatilis* distributes in the lower stratum (80-130 cm), but in the "Mizukawari" ponds where *Microcystis* of blue-green algae co-exists, the transparency being low, this rotifer distributes evenly over the whole strata.

4) When it is cloudy, *Br. plicatilis* crowds densely the surface layer in the transparent ponds.

5) In the "Mizukawari" pond where an electric mill is used for the airation of water, the distribution of the rotifer being deranged by the stirring the water, and it distributes evenly over the whole strata. And also in such a pond as this, no distinct diurnal change of the vertical distribution of the rotifer is recognized.

養鰻池の水変り時に異常増殖をした *Brachionus plicatilis*（輪虫類）がどのような垂直分布を示し，その分布に日変化が見られるかどうかは生態学的に興味深い問題であるのみでなく，実際の池の管理並に薬剤その他によるこの輪虫の control に対する重要な基礎問題でもある。湖沼における輪虫類の垂直分布に関しては多くの報告があるが，養鰻池について報告された例を知らない。筆者等は昭和30年5月から7月下旬に亘り，三重県津附近の4面の養鰻池の水変り時に大増殖をした *Br. plicatilis* O. F. MÜLLER の垂直分布とその日変化を観測し興味深い事実を見出したのでここにその結果を報告する。

本研究にあたり絶えず激励し種々の助言を与えられた本学水産学部長岡田弥一郎博士に感謝し，観測の1部に協力された当時の増殖学科学生田中敬八・倉田久昭両君に謝意

を表します。

観測方法

採水には西牧式注射器 (100 cc) を用い，ゴム管により底から 3 cm，50 cm，90 cm 並に表層から採水し，pH は比色法，溶存酸素は Winkler の沃素滴定法によつて測定した。輪虫類の個体数密度は約 100 cc の酸素瓶に各水層から上述の注射器で採水し，フォルマリン 15 滴を滴下し固定沈澱させ，遠心分離器にかけて 2～5 cc に濃縮し，その 1/4～1/10 をとつて計数盤に移し，その中に含まれる全個体数を計数し，池水 100 cc 中の個体数を算出した。

研究結果

1. Brachionus plicatilis の垂直分布

1) 例 1 (津市江戸橋大橋初次郎氏所有養鰻池)

昭和 29 年秋から昭和 30 年 5 月上旬まで池水は緑色を呈し好調であつたが，5 月 17 日頃から第 1 次の水変りとなり，水色は緑色から暗褐色に変り，澄んで来た。ウナギの摂餌量は 17 日から 22 日まで全くなかつた。5 月 22 日の測定結果によると，池水の水質は次のようであつた。水深 85 cm，透明度 84 cm，池水の塩素含有量 3.232 g/l，SiO_2 4.67 mg/l，Fe 0.61 mg/l，NH_4-N 2.86 mg/l，NO_3-N 0.01 mg/l，NO_2-N 0.03 mg/l，PO_4-P 1.28 mg/l，$KMnO_4$ 消費量 48.4 mg/l (不濾過水)。植物性プランクトンとしては硅藻類の *Chaetoceros Muelleri* が極く僅かに見られたのみである。

垂直分布の調査は 5 月 22 日午前 11 時に行つた。天候は終日曇天であつた。W. T.，pH，溶存酸素並に *Br. plicatilis* の垂直分布は Table 1 に示した。

Table 1. The vertical distribution of *Br. plicatilis* in H. Ohashi's pond in "Mizukawari".
Tsu City, Mie Pref., May 22, 1955.　Cloudy, Transparency 85 cm.

Depth cm	W. T. °C	Dissolved oxygen		pH	*Br. plicatilis* per 100 cc
		cc/l	%		
0	21.0	1.78	28.3	7.1	7715
35	—	2.09	33.2	7.1	5222
65	—	1.82	29.0	7.1	4114
82	—	1.44	22.9	7.1	3319

Table 1 に明かのように，この水変り池においては，pH は全層等しく 7.1 を示し，溶存酸素は 35 cm 層が最大で，底層はいく分少い。*Br. plicatilis* の成層は顕著で，最大は表層にあり，下層程減少している。この水変り池における *Br. plicatilis* の個体数密度は 33～77 個体/cc である。

2) 例 2 (津市江戸橋大橋房男氏養鰻池第 1 号池)

この観測は第 3 次水変り時に行つた。この水変りは 7 月 10 日頃からはじまり，池水は乳白色を帯び，著しく透明になり，11 日にはウナギ約 20 貫が斃死した。この日の調査

で *Br. plicatilis* の大増殖を認めた。観測は 7 月 13 日の午後 1 時に行つた。環境条件は次の通りである、晴天で日射強く，東風強く池面は風立ち，水色は灰乳色，透明度 76 cm，水深 135 cm，池水の塩素含有量 4.112 g/l，植物性プランクトン相は水変り前に多数存在した緑藻類の *Ankistrodesmus* sp. は全く消滅した。W. T.，pH，溶存酸素並に *Br. plicatilis* の垂直分布は Table 2 に示した。

Table 2. The vertical distribution of *Br. plicatilis* in F. Ohashi's pond in "Mizukawari".
Tsu City, Mie Pref., July 13, 1955.　Weather, fine; Transparency 76 cm.

Depth cm	W. T. °C	Dissolved oxygen cc/l	Dissolved oxygen %	pH	*Br. plicatilis* per 100 cc
0	31.5	1.90	36.2	7.3	1685
40	31.4	1.56	29.7	7.3	2975
80	31.0	1.13	21.5	7.3	16574
132	30.9	0.73	13.9	7.3	17285

Table 2 に明かのように，この水変り養鰻池においては，pH は全層同じく 7.3 であつたが，溶存酸素は下層程少くなつている。*Br. plicatilis* の成層は極めて顕著で，表層から 40 cm 層までは 17～30 個体/cc であるが，80 cm 以深は 166～173 個体/cc で，底層に密集していることは明かである。この日は晴天で雲はなく日射は強烈であり，その上池水は澄み，透明度は 76 cm であつた。この底層への密集はこの輪虫の強い光に対する負の趨光性によるものではないかと思われる。

3) 例 3 (津市島崎町大橋義男氏養鰻池)

7 月 9 日 (昭 30) には池水は暗緑色を呈し，他の 3 池と異り，藍藻類の *Microcystis flos-aquae* が多数浮游し，プランクトン動物としては，橈脚類の *Pseudodiaptomus inopinus* Burckhardt とその nauplius が多数見られたが，輪虫類の *Br. plicatilis* は殆んど見出し得なかつた。7 月 10 日にはウナギの摂餌は急激になくなり，1 部鼻上げをした。7 月 11 日の調査時には *Br. plicatilis* が爆発的に増殖し，池水 100 cc 中の個体数は *Br. plicatilis* 3020，*Pseudodiaptomus inopinus* 40，nauplius (Copepoda) 70，等のプランクトン動物の外に，プランクトン植物としては *Microcystis flos-aquae* (群体の大きさ直径 118×78 μ 以上のもの) 3140 を算えた。7 月 11 日～12 日にはウナギの摂餌は稍々見られた。

この垂直分布の観測は 7 月 13 日午後 1～2 時に行つた。晴天で日射強く，東風強く池面は波立ち，水深 92 cm，透明度 33 cm，池水は暗緑褐色を呈し，池水の塩素含有量は 2.952 g/l であり，W. T.，pH，溶存酸素並に *Br. plicatilis* の垂直分布は Table 3 に示した。

この池の水変りは植物性プランクトンの *Microcystis flos-aquae* (アオコ) が輪虫類の *Br. plicatilis* と共存する点で異り，*Microcystis* の炭酸同化作用によつて溶存酸素も多く，また pH も高い。*Br. plicatilis* の個体数密度も他の池に比して小さく，14～15 個体/cc 程度である。垂直分布も Table 3 に明かのように，溶存酸素，pH 共に表層は大きいが，著しい成層は見られない。また *Br. plicatilis* は全層に殆んど一様に分布している。本

Table 3. The vertical distribution of *Br. plicatilis* in Y. Ohashi's pond in "Mizukawari".
Tsu City, Mie Pref., July 13, 1955. Weather, fine; Transparancy, 33 cm.

Depth cm	W. T. °C	Dissolved oxygen cc/l	Dissolved oxygen %	pH	*Br. plicatilis* per 100 cc
0	31.6	4.10	78.1	8.0	1402
40	31.4	3.72	70.9	7.8	1552
87	31.4	3.72	70.9	7.8	1481

観測は例 2 と同日に，同一の天候条件の下で観測されたのにも拘らず，*Br. plicatilis* の垂直分布の様式が両池で著しく趣を異にするのは，例 3 の池では *Microcystis* が多数浮游し透明度が小さいのに反し，例 2 の池では植物性プランクトンが全く消滅し，池水は澄み，透明度が著しく大きいことが，*Br. plicatilis* の垂直分布に影響していると思われる。

4) 例 4 (津市栗真町屋町加藤慎太郎氏養鰻第 2 号池)

本観測は第 2 次水変り時に行つた。この池は 6 月 25 日 (昭 30) には植物性プランクトンの *Aphanocapsa* sp., *Ankitistrudesmus* sp., *Chaetoceros Muelleri* 等がよく繁殖し，池水は緑褐色を呈し，pH は 9.3，溶存酸素は 11.6 cc/l (221%) で水質の点からは好調であつたが, *Br. plicatilis* が増殖の傾向にあり，その個体数密度は 1298 個体/100cc で，ウナギの摂餌は不良であり，水変りの前兆であつた。そして 26 日朝ウナギ約 12 貫が斃死し，大部分のものが鼻上げをした。この水変りには前述の植物性プランクトンは全く消滅し，池水は著しく澄み，27 日には透明度は 69 cm, 28 ～ 29 日には 90 cm になり池底を透視出来た。pH は 7.7 ～ 7.9 に低下し，溶存酸素は最低 1.1 cc/l (19%) に減少した。動物性プランクトンとしては輪虫類の *Br. plicatilis* が大増殖を示し，28 日に最大個体数密度 7268 個体/100 cc に達した。

本調査における *Br. plicatilis* の垂直分布とその日週変化は 28 日から 29 日に亘つて観測した。6 月 28日は曇で夕刻に小雨があり, 29日は終日快晴であつた。この池においては観測期間中水車を使用していた。観測は水車から約 30 m 離れたところで行つたので，その作用による水の擾乱の影響があると思われる。

この水変り養鰻池における A. T., W. T., pH, 溶存酸素の垂直分布とその日変化は Table 4 に示し，また *Br. plicatilis* の垂直分布は Table 5 並に Fig. 2 に示した。

気温 (A. T.) は 6 月 28 日は曇で小雨もあつたので低く (26.0°C, 18 時), それから夜にかけて徐々に低下し，29 日の早朝 (4 時) に最低 23.6°C になり，日の出 (5 時) 頃から 8 時までに急激に上昇し，それからの上昇は徐々で，17 時には最高 31.9°C に達した。これに対応して水温 (W. T.) は 3 層共に日の出後から徐々に上昇し，15 時には最高 30.6 ～ 30.7°C に達した。表，中，底層間の温度傾斜は殆んど見られず，顕著な水温成層は見られない。

池水の pH は 7.6 ～ 7.9 で，29 日の日中には稍々上昇し最大 7.9 に達し，夜間には最低 7.6 を示したがその変化は極めて軽微であり，日較差は 0.3 に過ぎない。pH の垂直分布は水温と同様に上下層全く同じであり，成層は見られない。

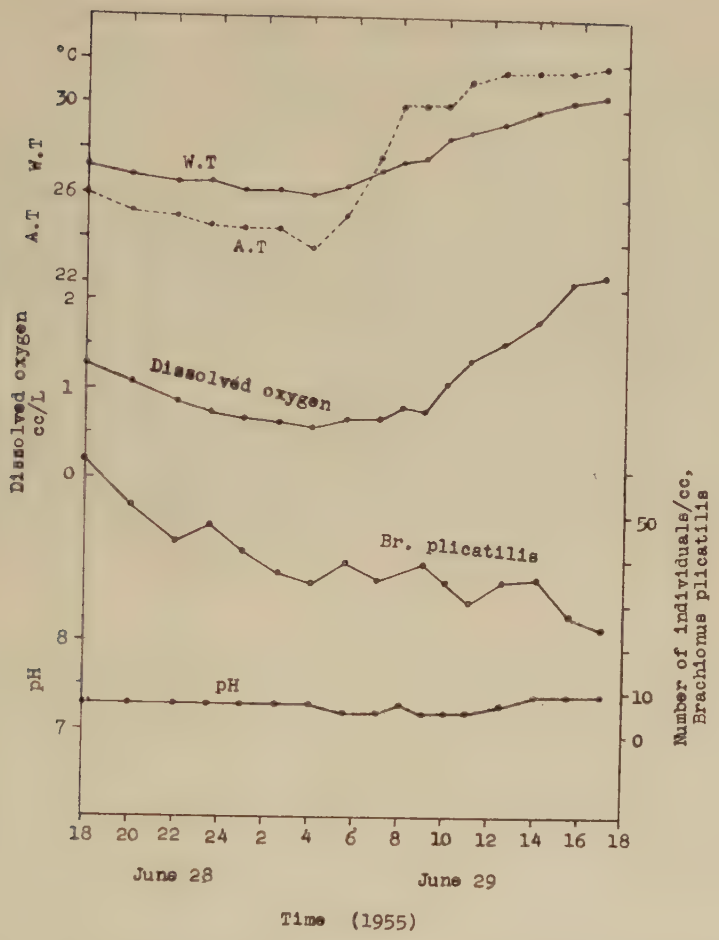

Fig. 1. Diurnal changes of W. T., dissolved oxygen, pH and the density of *Brachionus plicatilis* in Kato's eel-culture pond in "Mizukawari", Tsu City, Mie Prefecture.

池水の溶存酸素は最小 0.59 cc/l (10.4%)，最大 2.39 cc/l (45.5%) で，僅かではあるが，夜間は少くなり，日中は上・中・下各層が同様に増加し，最大 2.39 cc/l は 29 日の 17 時の時に見られた。この水変り池における pH 並に溶存酸素の日変化は残存する僅少の植物性プランクトンの光合成によるものであろう。溶存酸素の垂直分布は W. T., pH と同じく，上下層が殆んど同じで成層は見られない。

この水変り池におけるプランクトン動物相は殆んど輪虫類から成り，全動物性プランクトンの 97.8% は *Brachionus plicatilis* で，約 2% は *Pedalia fennica* が占め，その他に *Keratella cruciformis* var. *eichwaldi*, 橈脚類の *Pseudodiaptomus inopinus* 並に nauplius が僅かに見出されたのみである。優占種である *Br. plicatilis*の垂直分布と個体数密度の日変化は，Table 5 並に Fig. 2 に明かのように，この水変り池における *Br. plicatilis* の垂直分布には著しい成層は認められず，全水層にほぼ一様に分布している。またその垂直分布の日変化も明瞭ではない。然し注目すべきことは，*Br.*

Table 4. The Diurnal and vertical changes in W. T., pH and dissolved oxygen of Kato's pond water in "Mizukawari".

Tsu City, Mie Pref., June 28–29. 1955. Weather: June 28, cloudy; June 29, fine.

Transparency 90 cm.

Date	Depth / Time h.m.	Surface (3 cm) W.T. °C	Surface pH	Surface Dissolved oxygen cc/l	Surface Dissolved oxygen %	Middle (50 cm) W.T. °C	Middle pH	Middle Dissolved oxygen cc/l	Middle Dissolved oxygen %	Bottom (87 cm) W.T. °C	Bottom pH	Bottom Dissolved oxygen cc/l	Bottom Dissolved oxygen %	A.T. °C
June 28, '55	18	27.2	7.7	—	—	27.2	7.7	1.26	22.7	27.1	7.7	—	—	26.0
	20	27.0	7.7	1.09	19.5	26.8	7.7	1.25	22.3	26.5	7.6	0.91	16.2	25.2
	22	26.6	7.7	0.91	16.1	26.7	7.7	0.84	14.9	26.1	7.7	0.84	14.8	25.0
	23.30	26.7	7.7	0.71	12.6	26.7	7.7	0.73	13.0	26.4	7.7	0.79	14.0	24.6
June 29, 1955	1	26.3	7.7	0.68	12.1	26.2	7.7	0.65	11.5	26.1	7.7	0.69	12.2	24.5
	2.30	26.2	7.6	0.64	11.3	26.3	7.7	0.62	11.0	26.2	7.7	0.64	11.3	24.5
	4	25.8	7.6	0.62	10.9	26.2	7.7	0.59	10.4	26.0	7.7	0.54	9.5	23.6
	5.30	26.4	7.6	0.71	12.6	26.4	7.6	0.63	11.2	26.5	7.6	0.63	11.2	25.1
	7	27.8	7.6	0.69	12.5	26.8	7.6	0.66	11.8	26.8	7.6	0.65	11.6	27.7
	8	27.8	7.7	0.85	15.4	27.2	7.7	0.78	14.0	27.5	7.7	0.76	13.7	30.0
	9	28.2	7.6	0.79	14.4	27.6	7.6	0.70	12.7	27.4	7.7	0.74	13.4	30.0
	10	28.5	7.6	1.08	19.8	28.5	7.6	1.18	21.7	28.7	7.7	1.01	18.6	30.1
	11	28.9	7.6	1.36	25.1	28.8	7.6	1.34	24.7	28.6	7.7	1.29	23.8	31.2
	12.30	28.8	7.7	1.62	29.9	29.6	7.7	1.50	28.1	29.6	7.7	1.42	26.6	31.6
	14	29.3	7.8	1.84	34.3	30.3	7.8	1.81	34.3	30.0	7.7	1.68	31.6	28.6
	15.30	29.7	7.9	2.31	43.3	30.5	7.8	2.20	41.8	30.6	7.8	2.16	41.1	31.7
	17	30.7	7.8	2.24	42.7	30.6	7.8	2.39	45.5	30.6	7.8	2.27	43.2	31.9

Table 5. The diurnal changes in vertical distribution and the population density of *Br. plicatilis* in Kato's eel-culture pond in "Mizukawari".

June 28–29, 1955.

Date	Depth (cm) / Time h. m.	Surface (3)	Middle (50)	Bottom (87)	Mean
Jun. 28, 1955	18	7268/100 cc	5526/100 cc	5345/100 cc	6046.3/100 cc
	20	5235	5708	4489	5144.0
	22	4477	4179	4102	4252.7
	23.30	4285	4622	5225	4710.6
Jun. 29, 1955	1	4312	4092	3736	4046.7
	2.30	4282	2938	3570	3596.7
	4	2830	3665	3781	3425.3
	5.30	3188	4348	4060	3865.3
	7	3127	4574	2812	3504.3
	9	3635	3733	4377	3915.0
	11	2804	2957	3260	3007.0
	12.30	3053	3671	3847	3523.7
	14	3909	3740	3223	3624.0
	15.30	2606	3046	2320	2657.3
	17	2801	2777	2133	2570.3

plicatilis の個体数密度は 24 時間の間に顕著に減少している点である。即ち 6 月 28 日の 18 時には平均個体数密度は，6046 個体/100 cc であったが，1 日後の 17 時には 2570 個体/100 cc となり，約 1/2.4 に減少している。これは over population による餌料欠乏と環境条件の悪化による斃死のためと考えられる。この最大個体数密度に達して

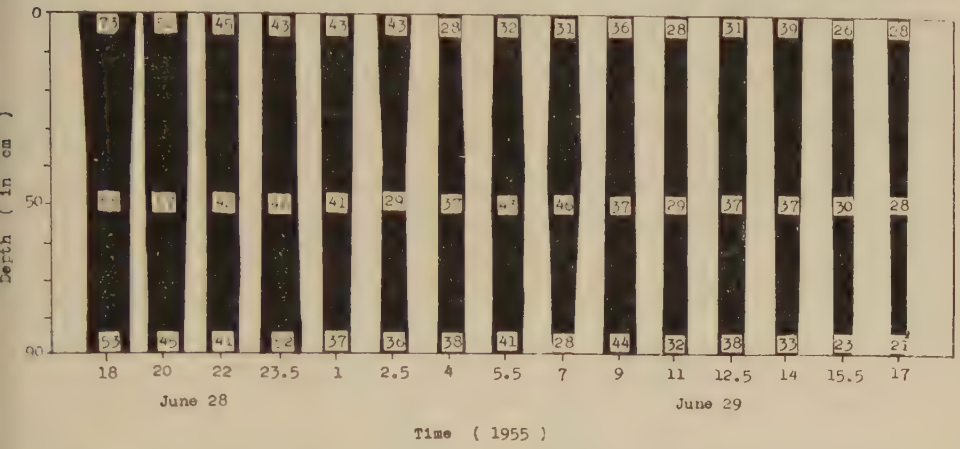

Fig. 2. The vertical distributions of *Br. plicatilis* in the "Mizukawari" eel-culture pond, Tsu, Mie Prefecture.
The figure in Fig. 2 shows the number of individuals of *Br. plicatilis* per cc.

からの急激な減少は，既に伊藤（1955c）が実験室における培養実験で明かにしている。

この例 4 の水変り池は例 1 並に例 2 の池と同様に，植物性プランクトンは殆んど消滅し，池水は澄み，透明度は 90 cm を示し極めて大きく，6 月 29 日の快晴で強い日射にも拘らず，*Br. plicatilis* の垂直分布が全層略々一様であるのは，水車の終日使用によつて水の攪乱によりその分布が乱されたのではないかと考えられうる。この点は W. T., pH, 溶存酸素等の水質からも首肯される。

2. Brachionus plicatilis の趨光性（予報）

水変り養鰻池に大増殖をした *Br. plicatilis* をプランクトン・ネットで採集し，透明なガラス瓶に入れ，強い直射日光の下におくと，間もなく器底に集合し，負の趨光性を示す。然しそのガラス瓶を実験室内の直射日光の当らない場所におくか，或いは曇天には光の来る明るい側に集合し，明かに正の趨光性を示すことが見られる。

この *Br. plicatilis* の趨光性並に趨地性を稍々詳しく知るために実験室において簡単な実験を行つた。方法の原理は Kikuchi (1938) によつた。第 1 次水変り中の第 2 号池（上記）から 6 月 14 日にプランクトン・ネットで採集した *Br. plicatilis* をその池水に濃縮して実験室に持帰し，長さ 19 cm，内径 2 cm，50 cc 容量の試験管に満たし，黒く塗つたコルク栓をし，暗室内に 1～2 時間放置して後，実験に使用した。趨地性は暗中と散光中について実験し，暗中の趨地性は試験管を垂直に保つて暗室内に 1 時間放置してその集合状況，集合位置から，また散光中の趨地性は，光源としてオリムパス光源ランプ（トランス附）を用い，弱い光 (Scale 2.2 以下) を白色スリガラスを通して上面か

ら垂直に光を当てて，管中におけるこの輪虫の集合状態とその行動から判定した。

趨光性は試験管に黒く塗つたコルク栓をし，水平に保ち，管底から光源ランプを横にして光を当てた。管瓶と光源ランプとの距離は 3 cm にした。光の強度はトランスによつて調節した。*Br. plicatilis* の趨光性並に趨地性は顕著ではなかつたが，其の結果は次のように要約することが出来る[1)]。

a) 趨地性—暗中においては明かに負を示し，多くの個体が表層に集合した。散光中では無反応で，全体に分散する傾向があつた。

b) 趨光性—弱い光（トランスの目盛 2.5 並に 5.0）に対しては明かに正の趨光性を示し，光源の側に集合する。またこの程度の光を絞りを小さくして，試験管の中央部に管と直角の方向に細い光の帯を作ると，両側からこの動物は明るい層に集合する。これに対し強い光（トランスの目盛 7.5 並に 10.0）に対しては，趨光性は明かに負になり，光源から遠ざからんとし，しかし遠くに移動したものは逆に光源に向つて移動する。そしてその行動に伴つて，*Br. plicatilis* の循環流が形成された。しかしその影響圏は光源の管底から 7～8 cm 位であつた。従つてこの結果から *Br. plicatilis* の趨光性は強光に対しては負であり，弱い光に対しては正であるといえよう。

考　　察

Brachionus plicatilis の上述の趨光性並に趨地性の実験結果から，前述の津附近の 4 面の水変り養鰻池における *Br. plicatilis* の垂直分布を考察して見る。

池水の上下循環並に擾動の少い静かな養鰻池においては，*Br. plicatilis* は日射の強い日中にはその負の趨光性によつて下降せんとし，光の弱いところに下降したものはその正の趨光性によつて上昇し，両方の釣合つた水層に集合するであろう。特に水変り池は一般に透明度が著しく大きいので底層に密集すると考えられる。これに属するものは例2であろう。*Microcystis*（アオコ）の共存した水変り池においてはそのため透明度は小さいので，晴天で日射の強い折にもその正の趨光性によつて表層に分布する傾向はあるが，趨地性は無反応であるから全層に分散する傾向があり，全体的には顕著な成層は見られなくなるだろう。この型に属するのは例 3 であろう。曇天並に雨天の場合にはその正の趨光性によつて表層に密集するものと考えられる。これに属するものは例1であろう。然し水変り養鰻池においては酸素補給の 1 助として習慣的に終日水車を運転する。これによつて浅い養鰻池（約 1 m）では池水は流動し，上下水層が混合し，W. T.，pH，溶存酸素等の水質の成層は乱され，また *Br. plicatilis* 等の垂直分布も全層略々一様になる傾向性がある。この型には例 4 が属するものと思われる。夜間における *Br. plicatilis* の垂直分布は，その顕著な負の趨地性によつて表層に集合すると考えられるが，その典型的な例は知られていない。例 4 の水変り池においては夜間においても *Br. plicatilis* の垂直分布は上下層殆んど同じであるが，これは前述したように水車の作用によるものと考えられる。

水変りの原因の 1 つである *Brachionus plicatilis* を何等かの薬剤の表面散布によつて撲滅するのには，上述の研究結果から，曇天で静かな日に実施した方が，*Br. plicatilis*

1) 光度の測定は本実験では行い得なかつた。また水温の影響も設備の関係で実験し得なかつた。詳細な研究が更に行われる必要がある。

は表層に集合しているので，より効果的であろう。

次に水変り養鰻池における輪虫類の個体数密度を見ると，上述の 4 面の池においては動物性プランクトンは殆んど純粋に *Brachionus plicatilis* のみより成り，その個体数密度は例 1 の池では 33～77 個体/cc，例 2 の池では 17～173 個体/cc，例 3 の池では，14～16 個体/cc，例 4 の池では 21～73 個体/cc である。これらの個体数密度を他の陸水における輪虫類のそれと比較して見る。PENNAK (1953) によると，山地湖や大きい貧栄養湖においては，輪虫類の個体数密度は 20 個体/l 以下であり，富栄養湖においても 40～500 個体/l 程度であり，1000 個体/l をこえるものは稀であり，汚染された陸水における輪虫類の最大個体数密度は，5800 個体/l であるという。これらに比し上述の 4 面の水変りした養鰻池における *Brachionus plicatilis* のみの個体数密度は驚くべきものであり，他の陸水における最大個体数密度を，5800 個体/l としても，これらの養鰻池のそれは，最小 2 倍，最大 30 倍の個体数密度であることは注目さるべき事柄であろう。これは養鰻池は過栄養型の湖沼であり，餌料としての植物性プランクトンの生産が極めて大きいことに起因することは明かである。

摘　　　要

1) 養鰻池における水変りの有力な原因である輪虫類の *Brachionus plicatilis* O. F. MÜLLER の垂直分布を津市の 4 面の水変り養鰻池において調査し，且つ実験室において *Br. plicatilis* の趨光性並に趨地性を決定する簡単な実験を行つた。

2) *Br. plicatilis* は強い光に対しては負の趨光性を示し，弱い光に対しては正の趨光性を示した。また暗中においては負の趨地性を示すが，散光中においては無反応であつた。

3) 日射の強い日中には，透明度の大きい水変り養鰻池においては，*Br. plicatilis* は底層 (80～130 cm) に分布するが，しかし藍藻類の *Microcystis* の水の華の共存した水変り養鰻池においては透明度は小さく，この輪虫は上下層殆んど一様に分布する。

4) 曇天で日射の弱い日中には透明度の大きい水変り池では，*Br. plicatilis* は表層に密集する。

5) 水車を使用する水変り池においては，池水の擾乱によつて輪虫の分布は擾乱され全層を通じ略々同様に分布する。またこのような池においてはその垂直分布の日変化も明瞭ではない。

6) *Brachionus plicatilis* の撲滅のための薬剤の散布は，従つて曇天でしかも静穏な日中に施行するのがより効果的であろう。

文　　　献

伊藤　隆，(1955a). 三重県養鰻池における水質とプランクトンとの関係。鰻のシンポジウム，p. 19～30. 日本水産学会中部支部。

———，(1955b). 養鰻池の水変りに関する研究。I. Brachionus plicatilis (輪虫類) によるプランクトン植物の捕食作用 (水変りの 1 因として). Report of Faculty of Fisheries, Prefectural University of Mie, Vol. 2, No. 1, p. 162～167.

———，(1955c). 養鰻池の水変りに関する研究。II. Brachionus plicatilis による水変りにおける $pH \cdot O_2$ の変化。Ibid. Vol. 2, No. 1, p. 168～177.

———, (1956). 養鰻池の水変りに関する研究。 III. 水変り池の Brachionus plicatilis に対する 漂白粉・硫酸銅・消石灰・海水並に淡水の致死濃度。Ibid. Vol. 2, No. 1, p. 317～324.

KIKUCHI, K., (1938). Studies on the Vertical Distribution of the Plankton Crustacea. II. Records of Oceanographic Work in Japan. Vol. 10, No. 1, p. 17～41.

菊池健三, (1939). 動物性プランクトンの垂直分布。動雑, Vol. 51, No. 5, p. 302～312.

PENNAK, R. W., (1953). Fresh-water Invertebrates of the United States, p. 180. New York.

Report of Faculty of Fisheries,
Prefectural University of Mie,
Vol. 2, No. 2, September 30, 1956.

養鰻池の水変りに関する研究

V. Brachionus plicatilis による"水変り"過程における水質の変化[1]

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Studies on the "Mizukawari" in Eel-culture Ponds.

V. The Changes of Water Qualities in the Process of "Mizukawari" Caused by Brachionus plicatilis.

(*With 2 Figures and 2 Tables*).

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Résumé

1. This experiment has been carried on through the researches in the change of water quality in the course of the "Mizukawari" which is caused by the abnormal reproduction of a brackish-water rotifer, *Brachionus plicatilis* O. F. MÜLLER and by the evident feeding of phytonannoplankton in the laboratory, and comparing this with that of the natural eel-culture ponds, to give an interpretation on the change of water quality in the process of "Mizukawari".

2. Taking *Merismopedia tenuissima* LEMM. of a blue-green alga as dominant species, and the green pond water containing 34.28×10^6 cells/cc, 15 L in total volumes as its medium, and adding *Br. plicatilis* gathered from other eel-culture pond in "Mizukawari", at the rate of a individual per cc of the medium. The changes of water quality with the growth of the rotifer, the decrease of phytoplankton, transparency, water colour, pH, dissolved oxygen, consumption of $KMnO_4$, alkalinity, NH_4-N, NO_2-N, NO_3-N and PO_4-P, were traced.

3. *Br. plicatilis* shows a great increase; reaches the maximum population density, 135–137 individuals/cc from four to five days after, suddenly dying after the sixth day and abated into 8.6 individuals/cc eight days after. And when the great growth occurred, there grow D♀, and many dormant eggs formed to be deposited at the bottom of the experimental aqualium.

4. By the feeding of *Br. plicatilis* the number of the cells of phytoplankters suddenly decreases to the minimum eight days after to show 1/84 as few as before the experiment. This decrease occurred distinctly with those of under 12–15 μ of size.

5. The transparency of the medium becomes suddenly high with the decrease of phytoplankton, and the water colour, depending upon the rate of the mixture of phytoplankton with the rotifer and the quantities of both, has changed in the order of green, yellow green, light brown into colourless.

6. The pH of the medium decreases from 9.2 down to 7.6, and its minimum comes co-temporarily with the maximum population density of the rotifer.

1) 本研究の1部は昭和30年度文部省科学研究助成金によつたものである。

7. The dissolved oxygen suddenly decreases from 9.40 cc/L (159.9%), to the minimum 1.03 cc/L (17.0%) three days after.

8. Alkalinity did not show distinctly, but slightly increases after three days.

9. The consumption of $KMnO_4$ of the unfiltered water has decreased with the decrement of phytoplankton.

10. NH_4–N, NO_2–N, NO_3–N, PO_4–P of nutrients have shown their distinct increases since the increasing period of the rotifer, and especially after its death; perhaps, it is because they are dissolved out from the corpees.

11. The phenomena mentioned above well coincide with those of the "Mizukawari" brought with the great increase of the rotifer in the natural eel-culture ponds.

第1報 (伊藤 1955 b) 並に第2報 (伊藤 (1955 c) に輪虫類の *Brachionus plicatilis* O. F. Müller が大増殖をしながら植物性プランクトンを殆んど食い潰すことによつて，養鰻池における水変りに酷似する現象を実験室で作ることに成功したことを報告し，その結果から少くとも輪虫類の大増殖を伴つた水変りは，輪虫類の大増殖とその顕著な植物性プランクトンの捕食作用が水変りの有力な1因になる可能性を指摘した。

本研究は輪虫類の *Brachionus plicatilis* による"水変り"過程において溶存酸素・pH のみでなく他の水質がどのように変化するか。果して天然の養鰻池における水変り時のような変化過程をとるか。プランクトン植物相の相異によつてその水変りはどう影響されるか等の点を明かにするためにこの実験を行つた。

本研究に当り種々の助言を与えられと本学水産学部長岡田弥一郎教授，並にプランクトン植物の同定に関し種々御教示戴いた本学水産学部浮游生物学教室赤塚孝三講師に謝意を表します。

材料並に方法

Brachionus plicatilis (輪虫類) の材料。津市栗真町屋町加藤養魚場第3号養鰻池 (池水の塩素含有量 7.336‰) から昭和30年9月21日に採集した。この池の動物性プランクトンには夥しい *Br. plicatlis* の外に橈脚類の *Pseudodiaptomus inopinus* Burckhardt と少量の nauplius larva と polychaeta larva が混在していた。これらの動物性プランクトンから *Br. plicatilis* のみを殆んど純粋に近い状態で得るのには次の方法によつた。即ちプランクトン・ネットで動物性プランクトンを池水中に濃縮して実験室に持参し放置する。約 3〜4 時間後には最も弱い *Pseudodiaptomus* が斃死し器底に沈澱する。その上層水を他の容器に移し，更に24時間放置すると，全部の polychaeta larva と大部分の nauplius larva は死滅沈澱し，*Br. plicatilis* のみが生残る。この上層水を他の容器に移して実験に供した。最後の容器中における *Br. plicatilis* の個体数密度は平均 4320 個体 / cc であつた。

池水並に植物性プランクトンの試料。津市島崎町黒宮養魚場第2号養鰻池 (池水の塩素含有量 3.548‰, pH=9.6) から9月22日朝採水した池水そのままを試料に用いた。この池水は鮮緑色を呈し，輪虫類は勿論他のプランクトン動物も殆んど見られなかつた。この池水約 30 L を実験室に持参し，プランクトン・ネットで濾過してプランクトン動物を取除いてその濾液を試料として実験に供した。この濾過した池水中の植物性プランクトンの組成と，池水 1 cc 中の各種類の細胞数は次のようであつた。

藍　藻　類 (Cyanophyceae)	
Merismopedia tenuissima	29.436×10^6 cells/cc
Chroococcus limneticus	0.069
Aphanocapsa sp.	3.538
緑　藻　類 (Chlorophyceae)	
Dictyosphaerium pulchellum	0.171
Scenedesmus obliquus	0.069
Other Chlorophyceae	0.411
硅　藻　類 (Diatomaceae)	
Cyclotella glomerata	0.343
Nitzschia closterium	0.069
Chaetoceros Muelleri	0.069
Navicula sp.	0.069
計	34.244×10^6 cells/cc

従つて藍藻類の *Merismopedia tenuissima*, *Aphanocapsa* sp. が最も卓越し，特に前者は細胞数の点から全植物性プランクトンの 86% を占め優占種であり，後者は全体の 10% を占めている。従つてこの池水の植物性プランクトンは藍藻類の *Merismopedia*, *Aphanocapsa* によつて殆んど占められていると考えてよい。この優占群の大きさを見ると，両種共に群体を形成しているが，その群体の大きさは *Merismopedia* は 5～30 μ, *Aphanocapsa* は 2～3 個の群体から成り，その大きさは 2～6 μ である。この試料としての池水の植物性プランクトンの大きさの組成を見ると， 3 μ 以下の所謂 micron-algae に属するものが 50%, 3～6 μ に属するものか 20%, 6～ 9 μ に属するものが 18%, 9～12 μ 属するものが 6%, 12～15 μ のものが 3%, 15～18 μ のものが 2%, 20 μ 以上のものが 1% を夫々占めていた。従つてこの池水の植物性プランクトンは約 94% が大きさ 12 μ 以下の藍藻類に属する *Merismopedia tenuissima*, *Aphanocapsa* sp. から構成されていると見てよい。

実 験 方 法。 上述の *Merismopedia-Aphanocapsa* 池水 15 L を大型角水槽 (26.5×21×29.5 cm) に入れ，それに上記の輪虫水 35.2 cc (池水 1 cc について 10 個体の割合) を加えた。これと同型同容の水槽に輪虫を加えないものを control として，両水槽を直射日光のあたらない南側(室内)の机上において，両水槽の水質の変化を追跡し比較した。水質要素は次の事項につき次の方法で分析した。透明度は直径 10 cm の白色円板により，水色は不充分ではあるが肉眼で，水温は棒状寒暖計で，pH は比色法により，溶存酸素は Winkler の沃素滴定法により，B. C. P. アルカリ度は菅原 (1942, p. 532), $KMnO_4$ 消費量は三宅・松居 (1942, p. 134) のアルカリ法により不濾過水について，栄養塩類は濾過水について行い， NH_4–N は Nessler 法 (三宅・松居, 1942, p. 163), NO_2–N は G. R. 試薬 (三宅・松居, 1942, p. 169), NO_3–N はヂフエニルアミン法 (吉村, 1939, p. 41), PO_4–P は Denigés-Atkins 法 (三宅・松居, 1942, p. 182) により夫々分析した。

プランクトン植物量の変化は細胞数によつた。計数方法は伊藤 (1955 b, c) と同様にして，群体を形成しているものは細胞数を計数し，1 c.c. 中の細胞数として算出した。輪

虫類の *Brachionus plicatilis* の個体数密度は伊藤（1955，c）と同様にし，今回は 20 cc を中層から採水してその中の個体数を計数し，1 cc 中の個体数を算出した。

実験は昭和 30 年 9 月 22 日から 10 月 1 日に亘つて行つた。

実　験　結　果

本実験の結果は Table 1 並に 2，Fig. 1 並に 2 示した。

1. *Brachionus plicatilis*（輪虫類）の個体数密度の変化

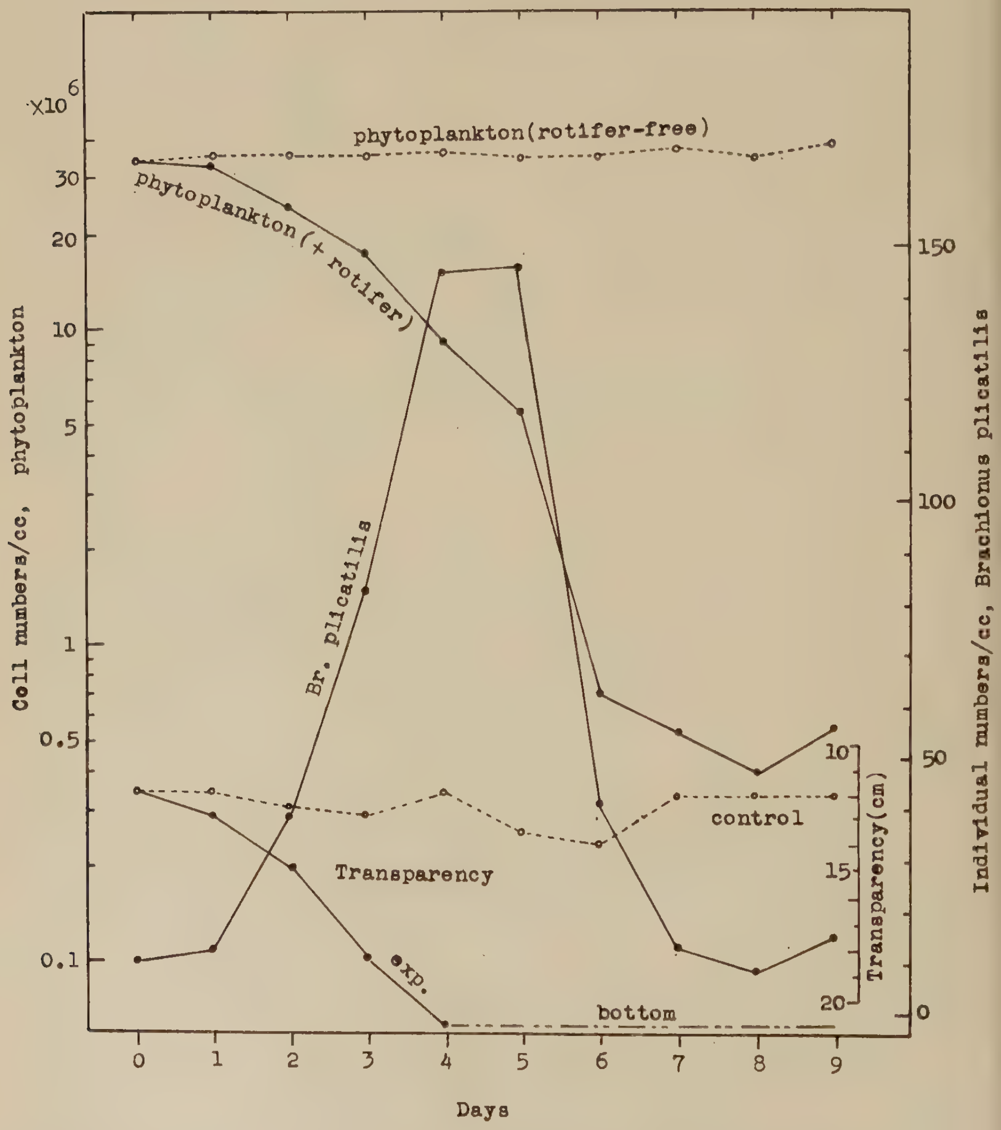

Fig. 1. Changes in cell numbers of phytoplankton, population density of *Brachionus plicatilis* and transparency of the medium in the process of "Mizukawari" caused by *Br. plicatilis* O. F. Müller in the laboratory.

池水 1 cc について 10 個体の割合で加えた *Br. plicatilis* のその後の増殖速度は驚くべきもので，2 日後には 28.5 個体，4 日後には 135.1 個体，5 日後には最大個体数密度

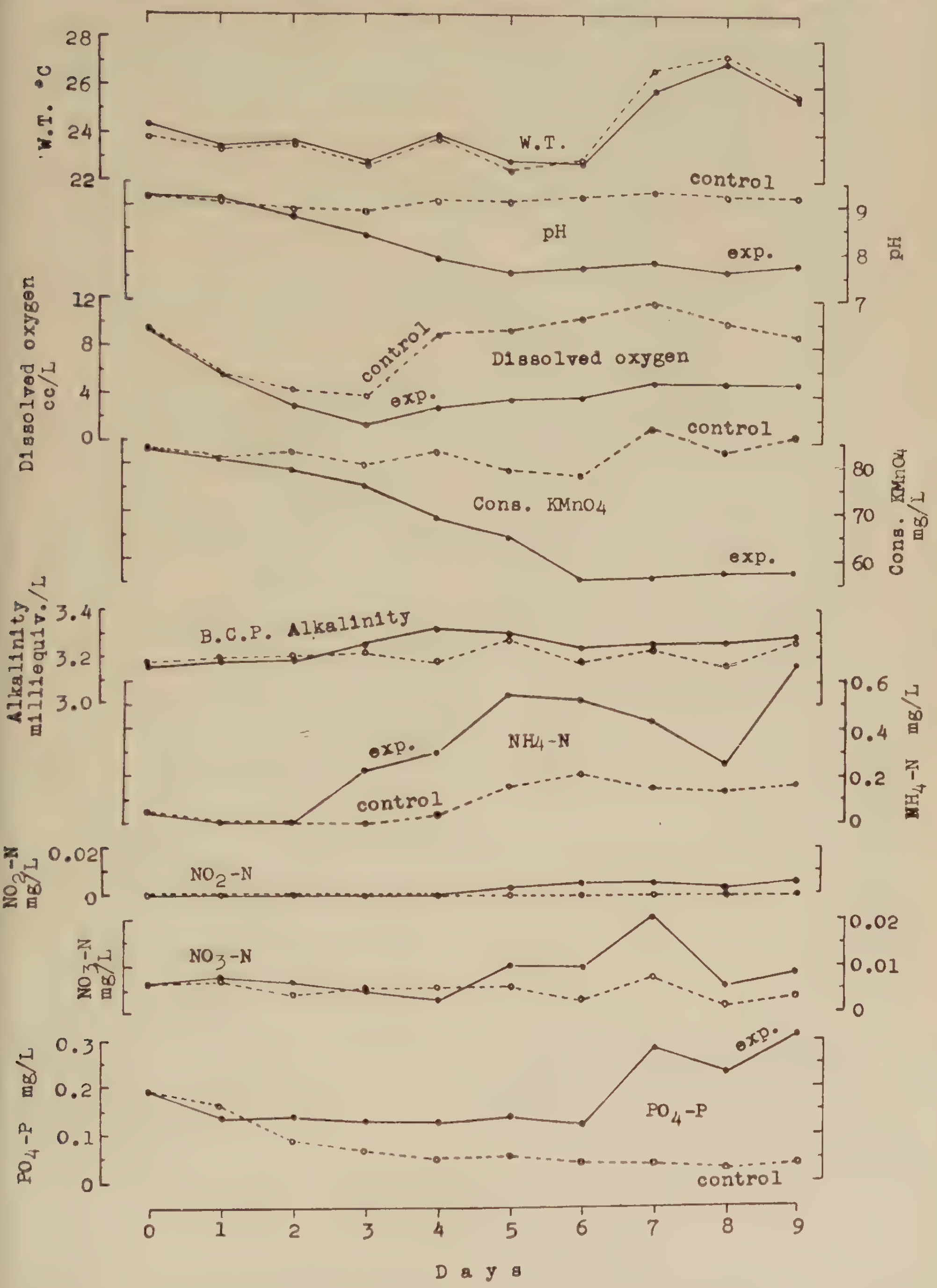

Fig. 2. Continue.—Changes of water qualities in the course of "Mizukawari" caused by *Br. plicatilis* in the laboratory.

Table 1. The experiment.—Changes of water qualities in the process of "Mizukawari" caused by ***Brachionus plicatilis*** in the laboratory.

Medium: Green pond water, that is contains 34.28×10^6 cells/cc of phytonannoplankton, it mainly consists of a blue-green alga, ***Merismopedia tenuissima***.

Rotifer: *Br. plicatilis* was inoculated the medium at a rate of 10 individuals per cc.

		Culture days									
		0	1	2	3	4	5	6	7	8	9
Time (h. m.)		12.45	12.20	12.05	11.30	12.25	11.45	12.30	12.15	12.15	11.45
Weather		Fine	Fine	Fine	Fine	Cloudy	Cloudy	Cloudy	Fine	Fine	Fine
Water colour		Green	Green	Yellow Green	Yellow Brown	Yellow Brown	Yellow Brown	Clear	Clear	Clear	Clear
Transparency	cm	12	13	15	18.5	21 (Bottom)	Bottom	Bottom	Bottom	Bottom	Bottom
W. T.	°C	24.5	23.6	23.8	22.9	24.0	22.9	22.8	25.9	27.0	25.4
pH		9.2	9.2	8.8	8.4	7.9	7.6	7.7	7.8	7.6	7.8
Dissolved oxygen	cc/L	9.40	5.51	3.09	1.03	2.91	3.48	3.84	5.06	4.49	4.76
	%	159.9	92.0	51.9	17.0	47.4	55.8	61.3	85.0	77.4	79.6
Alkalinity	milliequiv./L	3.146	3.174	3.186	3.256	3.326	3.298	3.242	3.243	3.256	3.270
Cons. $KMnO_4$	mg/L	82.5	81.1	78.9	76.2	69.0	65.4	56.5	57.4	58.7	58.3
NH_4-N	mg/L	0.057	tr.	tr.	0.235	0.303	0.556	0.526	0.444	0.263	0.667
NO_2-N	mg/L	tr.	tr.	tr.	tr.	tr.	0.004	0.006	0.005	0.003	0.005
NO_3-N	mg/L	0.007	0.009	0.007	0.005	0.003	0.011	0.010	0.021	0.006	0.009
PO_4-P	mg/L	0.196	0.133	0.143	0.125	0.131	0.188	0.167	0.286	0.231	0.313
Phytoplankton:	cell numbers/cc	34.28×10^6	33.50	24.56	17.69	9.19	5.75	0.719	0.680	0.406	0.679
Br. plicatilis:	number of ind./cc	10	12.3	28.5	73.0	135.1	136.8	32.0	13.5	8.6	17.2

Table 2. Control (rotifer-free)

		Culture days									
		0	1	2	3	4	5	6	7	8	9
Time (h. m.)		12.45	12.20	12.05	11.30	12.25	11.45	12.30	12.15	12.15	11.45
Weather		Fine	Fine	Fine	Fine	Cloudy	Cloudy	Cloudy	Fine	Fine	Fine
Water colour		Green	Green	Green	Green	Green	Yellowish Green	Yellow Green	Green	Green	Green
Transparency	cm	12	12	13	13	12	13.5	14	12	12	12
W. T.	°C	23.9	23.6	23.8	22.8	23.9	22.5	22.9	26.7	27.2	25.5
pH		9.2	9.1	8.9	8.9	9.1	9.1	9.2	9.3	9.2	9.2
Dissolved oxygen	cc/L	9.33	5.68	4.26	3.93	9.13	9.38	10.26	11.86	10.30	9.10
	%	156.8	94.8	71.6	65.0	148.7	149.4	164.4	202.0	177.0	152.2
Alkalinity	milliequiv/L	3.188	3.201	3.216	3.228	3.188	3.284	3.188	3.243	3.160	3.270
Cons. $KMnO_4$	mg/L	83.4	80.2	82.5	78.0	83.4	78.9	77.6	87.9	83.4	87.0
NH_4-N	mg/L	0.057	tr.	tr.	tr.	0.038	0.179	0.220	0.161	0.144	0.170
NO_2-N	mg/L	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.
NO_3-N	mg/L	0.006	0.007	0.004	0.006	0.006	0.006	0.003	0.008	0.002	0.004
PO_4-P	mg/L	0.189	0.174	0.089	0.069	0.053	0.059	0.043	0.039	0.029	0.036
Phytoplankton: cell numbers/cc		34.28×10^6	34.50	34.81	35.12	36.38	34.06	35.35	37.00	34.19	38.94
Br. plicatilis		0	0	0	0	0	0	0	0	0	0

136.8個体/cc に達した。しかし6日後から逆に急激に斃死がはじまり，32個体になり，8日後には 8.6個体/cc に減少した。この増殖傾向は第2報（伊藤，1955 c）のそれと全体的にはよく一致する。しかし前報においてはその最大個体数密度は実験開始後 3 日後にあるが，今回は 4～5日後に存在しやや遅い。これは本実験では水温が稍々低く，また餌料としてのプランクトン植物相の相異によるのではないかと考えられる。次にこの輪虫の 1～3 日後の驚くべき増殖は amictic egg（従来は夏卵 summer egg と呼ばれていた）によるものであり，注加前には amictic egg をもつた ♀♀ は少数で，且つその携帯卵数は普通 1 個であつたが，1～3 日後には amictic egg を附けた ♀♀ の個体数が急激に増加し，且つ 1 個体の携帯した卵数も 2 個，3 個と増加し，中には 6 個附着している個体も見られた。更に注目すべきことはこの輪虫の大増殖の際に，特に最大個体数密度の時期に体内に耐久卵（dormant egg，或いは冬卵 winter egg，休眠卵 resting egg）を持つた D♀ が顕著に出現し，この D♀ は活動性が鈍く器底に沈降，斃死し，その体内容物は分解し，被甲中に耐久卵を保持したまま，或いはそれから游離した耐久卵が器底に多数沈積した。耐久卵は黄褐色を呈し，長径約 120 μ，短径約 74 μ の楕円形を呈する。実験終了後（9 日後）水槽中をよく攪拌しながら，沈澱物を一様に分布させるようにして，その中から 20 cc をとり，その中に含まれる耐久卵の数を計数し，1 cc 中の数を算出したところ，28.2 個であつた。これは最大個体数密度（136.8 個体/cc）の約 20% に相当する。またこの耐久卵の分布密度は底面積 557 cm² (26.1×21 cm)，水柱の深さ約 20 cm の水槽の底面 1 cm² について 573 個/cm² となる。従つて *Br. plicatilis* の耐久卵の形成量も極めて顕著であるといえよう。水変り時における *Br. plicatilis* の増殖機構並に耐久卵の形成に関する詳細は別報にのべる。

2. 植物性プランクトンの変化

池水中の植物性プランクトンの全細胞数の変化は Fig. 1 に明かのように，*Br. plicatilis* を加えない control においては殆んど変化は見られなかつたが，加えた実験水槽では顕著な減少が見られ，細胞総数は 2 日後には $^1/_{1.4}$ に，4 日後には $^1/_{3.7}$ に，6 日後には $^1/_{48}$ に，8 日後には最小 0.406×10^6 細胞/cc になり，実験前の $^1/_{84}$ に減少した。この減少速度は伊藤 (1955 b) の No. 4 (*Br. plicatilis* を 10 個体/cc に加えた場合）に略々類似するが，それより速度は稍々小さい。これは水温が低く，*Br. plicatilis* の増殖速度が稍々おそく，また餌料としてのプランクトン植物の種類が異り，前報においては micron-algae に属する *Synechococcus* であり，本研究においては優占種が藍藻類の *Merismopedia tenuissima* であり，これは群体を形成し，相当に大きいので，*Br. plicatilis* の餌料として或る種の制限と抵抗が原因となつているように思われる。一方プランクトン植物の大きさの組成の変化を見ると，輪虫を加えない control においては，実験前と 9 日後とでは殆んど差異は見られなかつたが，実験水槽においては，大きさの組成の変化は顕著であり，減少は 3 μ 以下のものが最も大きく，3～9 μ のものがこれに次ぎ，12 μ 以上の大きさのものは殆んど変化していなかつた。従つて *Br. plicatilis* の捕食作用の限界は 10～12 μ 位にあるものと考える。*Br. plicatilis* の捕食作用とプランクトン植物の大きさとの関係についての詳細は別報にのべる。

3. 水 質 の 変 化

1) 水　温。 両水槽に顕著な差異はなく，実験期間中 22.5°C から 27.2°C に亘て変化した。しかし 7〜8日 後の水温は植物性プランクトンの多い control の方が実験水槽より稍々高い。これは中村 (1949) が指摘したように，太陽輻射熱の吸収が植物性プランクトンの多い緑色を呈した control の方が大きいことに原因していると考えられる。

2) 水色並に透明度。 輪虫を加えない対照水槽においては 5〜6 日後いく分水色は黄味を帯びた緑色となり，透明度は 11.5〜14 cm になり稍々大きくなつたが，他は常に緑色を保ち，透明度は約 12 cm 前後で実験水槽と著しい対照をなしていた。輪虫を加えた実験水槽では植物性プランクトンの減少と *Br. plicatilis* の大増殖に伴つて水色は 1 日後までは緑色を呈していたが，2 日後には黄緑色になり，稍々澄みはじめ，それから褐色系を増し，4〜5 日後には黄褐色に変り，著しく澄み，6 日後からは殆んど透明に近くなつた。この水色の変化系列は緑色系を与える植物性プランクトンと，黄褐色乃至赤褐色系を与える *Br. plicatilis* の大集団との混合割合に原因し，また池水が透明になるのは植物性プランクトンの捕食による消滅と最大個体数密度に達してからの *Br. plicatilis* の斃死に起因することは明かである。

3) pH. 対照水槽では実験期間中 pH は 8.9〜9.1 を示したが，実験水槽では 1 日後から顕著な差を生じ，5 日後に最低 7.6 を示した。これは *Br. plicatilis* の最大個体数密度と一致する。その後も常に対照水槽より約 1.5 位低い。

4) 溶 存 酸 素。 対照水槽においても日々変動が大きいが，全体的に見ると，輪虫を加えた実験水槽では 2 日後から差が現われ，3 日後には最小 1.03 cc/L (17.0%) が見られ，実験期間対照水槽により溶存酸素は著しく少い。

5) B. C. P. アルカリ度。 対照水槽においては全体的には殆んど変化はないが，実験水槽では 3 日後から大きくなり，その状態が 5 日後まで続いた。

6) $KMnO_4$ 消費量。 対照水槽では 77.6〜37.0 mg/L に亘つてその変動は大きいが全体的傾向としては殆んど変化はない。しかし実験水槽における傾向性は顕著であり，植物性プランクトンの減少と並行的で，1 日後から減少しはじめ，3〜6 日後間の減少が著しく，6 日後に最小 56.5 mg/L が見られ，その後殆んど変化はない。この不沪過水の $KMnO_4$ 消費量の変化は輪虫類の大増殖に影響されることは少く，植物性プランクトンの減少に支配されることが大きい。

7) 栄 養 塩 類。 NH_4–N は 3 日後の *Br. plicatilis* が大増殖をする時期から顕著に増加しはじめ，NO_2–N 並に NO_3–N は 5 日後から著しく増加している。 PO_4–P には 7 日後から急激な増加が見られる。これらの N, P の増加は *Br. plicatilis* の増殖期から見られ，特に最大個体数密度に達してからの斃死期に顕著であるので，恐らく輪虫類の排泄物，特にその斃死体から分解溶出するものと考えられる。稲葉 (1937) は天然の養鰻池の水変り時における栄養塩類の著しい増加は植物性プランクトンの枯死体から溶出すると考えたが，本実験の結果から，*Br. plicatilis* の排泄物，特にその斃死体からの溶出を考える方がより合理的である。この考えは吉井・渡部 (1956) の核分裂生成物による実験結果で裏付られた。

考　　察

本実験における輪虫類の *Br. plicatilis* の増殖様式，プランクトン植物の減少，水色並に透明度の変化，pH，溶存酸素の低下は，第1報並に第2報（伊藤 1955 b 並に c）の試水が藍藻類の *Synechococcus* 池水の場合の結果と全く一致する。また本実験における水質の変化過程は天然の養鰻池における輪虫類の異常増殖を伴つた“水変り”の現象（稲葉 1937; 稲葉・山本 1939; 稲葉・清石 1942; 伊藤 1955 a; 伊藤・岩井，未発表）と全く一致している。従つて本実験における輪虫類の *Br. plicatilis* による水変り類似の現象並に天然の養鰻池における輪虫類の大増殖を伴つた水変りは次のように説明出来よう。

輪虫類の異常増殖とその顕著な捕食作用によつて池水中の植物性 nannoplankton は急激に減少し，その結果池水の透明度は著しく増大し，水色は植物性プランクトン量と輪虫類の個体数密度に支配され，両者の混合割合によつて緑色から黄褐色，褐色を経て無色になる。植物性プランクトンの急減に伴つてその炭酸同化作用は急激に衰え，更に輪虫類の呼吸作用によつて溶存酸素は減少し，逆に炭酸ガスが増加し，pH は低下する。植物性プランクトンの減少に伴つて池水の $KMnO_4$ 消費量は減少する。NH_4-N，NO_3-N，NO_2-N，PO_4-P 等の栄養塩類は植物性プランクトンによる同化がなくなり，その上最大個体数密度に達してからの輪虫類の斃死体の分解によつて著しく増加する。溶存酸素の減少によつて底泥中の $Fe^{\cdots}$ は還元されて $Fe^{\cdot\cdot}$ として水中に溶出し，また水中の硫酸塩は還元されて硫化水素を生ずるであろうことは，水変り時には池水が硫化水素臭を放ち，また養鰻池の多くは海岸地帯にあり多量の硫酸塩を含有することから容易に考えられる。水変り時における養殖魚の摂餌不良，鼻上げ，斃死等の異常現象は溶存酸素の欠乏，炭酸ガス，硫化水素，メタン等の有害物質の過剰に起因すると考えられる。また水変りの程度に差異の見られるのは，水変りの変化速度並に変化量，有害物質の生成速度並に生成量と密接な関係があるように思われるが，これらの関係については将来の研究に俟つべきである。

次に養鰻池における“水変り”の原因について考察する。植物性プランクトンがよく繁殖し緑色を呈する養鰻池においては，日中酸素欠乏を来たし，養殖魚の摂餌不良，鼻上げ，斃死等の異常現象は全く見られない。このような異常現象は植物性プランクトンが急激に減少するか，消滅する所謂“水変り”の場合に限られている。植物性プランクトンのこの急激な減少をひきおこす原因が“水変り”の原因と思われる。養鰻池における植物性プランクトンの急激な消滅の原因に関しては，次の3者間の平衡関係を仮定することが出来よう。

$$\text{池水の物理化学的性質} \overset{(1)}{\longleftrightarrow} \text{植物性プランクトン} \overset{(2)}{\longleftrightarrow} \text{動物性プランクトン}$$

養鰻池はその立地，投餌，集約的養魚という性格から見て一般的に過栄養型に属し，植物性プランクトン並に動物性プランクトンの生産量はおどろくべきもので，透明度は普通15～30 cm 位である。また海岸地帯に存在するので相当量の塩分を含有し，汽水に属するものが多く，池水の塩分がプランクトン植物相並にプランクトン動物相を支配し，これらが“水変り”の程度に大きく関与しているように思われる。正常の養鰻池では上述の3者間に平衡が保たれ，植物性プランクトンの炭酸同化作用による酸素の供給によつて養魚

が成立している。そしてこの平衡関係が破れた場合が“水変り”と考えることが出来よう。

(1) の平衡が破れた場合は動物性プランクトンの大増殖を伴わない“水変り”であり，この場合の水変りにおける植物性プランクトンの急激な消滅の水質上の誘因としては，稲葉 (1937) は栄養塩類 (N, P) の欠乏，腐植酸その他の還元物の底泥からの溶出を仮定し，輪虫類の異常増殖は水変りの結果と考えた。松江 (1954)，松江・平野 (1955) は *Scenedesmus* の培養実験によつて栄養塩類が豊富に存在する場合には，水中の炭酸の不足が水変りの原因になる可能性を指摘した。以上の 3 要因が従来“水変り”の誘因と考えられているものである。しかし実際の養鰻池においては消費者としての動物性プランクトン，特に輪虫類，繊毛虫類の大増殖を伴わない“水変り”は現在までに確認されていない。

第 2 にこの植物性プランクトンの急激な減少の原因としては，プランクトン植物自身の生物学的特性，季節的遷移，社会的干渉等も関与していると考えられる (伊藤 1955a) が，これ等に関しては養鰻池のプランクトン植物相，その季節的遷移の様式を多くの池について明かにすることが今後の重要な課題であろう。

第 3 に，(2) の平衡の破れた場合，すなわち被捕食者としての植物性プランクトンと捕食者としての動物性プランクトンとの間の平衡関係が破れた場合，換言すると動物性プランクトンが異常増殖し，その捕食作用が植物性プランクトンの増殖をはるかにこえた場合の“水変り”である。この食物連鎖による植物性プランクトンの急減による養鰻池の“水変り”については従来全く注意されなかつた。第 1 報，第 2 報並に本実験の結果から，また実際の養鰻池の“水変り”時には殆んど例外なく輪虫類の異常増殖が伴つている点等から見て，輪虫類の大増殖とその顕著な植物性プランクトンの捕食作用が“水変り”の有力な 1 因であることは間違いないであろう。

摘　　要

1) 本実験は輪虫類の *Brachionus plicatilis* O. F. Müller の異常増殖とその顕著な植物性プランクトンの捕食作用による“水変り”過程における水質の変化を追跡し，天然の養鰻池の水変り時における水質変化を解釈するために行つたものである。

2) *Br. plicatilis* は養鰻池から採集し，植物性プランクトンも藍藻類の *Merismopedia tenuissima* を優占種とする緑色を呈し，総細胞数 34.28×10^6/cc を含んだ養鰻池水を用いた。緑色池水に *Br. plicatilis* を池水 1 cc について 10 個体の割合に加え，其の後の輪虫の増殖，植物性プランクトンの細胞数の減少，透明度，水色，pH，溶存酸素，$KMnO_4$ 消費量，アルカリ度，NH_4–N，NO_2–N，NO_3–N，PO_4–P 等の水質の変化を調べた。

3) *Br. plicatilis* は大増殖を示し，4～5 日後に最大個体数密度 135～137 個体 / cc に達し，6 日後から急激に斃死し，8 日後には 8,6 個体 / cc に減少した。この大増殖は単為生殖による。またこの大増殖期に D♀ を生じ，多数の耐久卵が形成され，器底に沈澱した。耐久卵の形成量は 28.2 個 / cc で，最大個体数密度の約 20% に相当し，また器底 1 cm^2 の分布密度は 573 個であつた。

4) 植物性プランクトンの細胞数は *Br. plicatilis* の捕食によつて急激に減少し，4 日後には 1/4 に，6 日後には 1/48 に，8 日後には最少になり実験前の 1/84 に減少した。この

減少はプランクトン植物の大きさから見ると，3μ 以下のものが最大で，3〜9 μ のものがこれに次ぎ，12 μ 以上のものは殆んど減少は見られない。従つて *Br. plicatilis* の捕食可能限界は 12 μ 以下のものと推定される。

5) 池水の透明度は，植物性プランクトンの減少に伴つて急激に大きくなり，また水色は植物性プランクトンと輪虫類の混合割合と両者の量に支配され，緑色→黄緑色→黄褐色→無色の変化系列をたどつた。

6) 池水の pH は 9.2 から 7.6 に低下し，この最低は輪虫の最大個体数密度の時期と一致する。

7) 溶存酸素は 9.40cc/L (159.9%) から急激に減少し，3 日後に最小になり，1.03 cc/L (17.0%) に減少した。

8) アルカリ度は顕著ではないが，3 日後から稍々大きくなつた。

9) 不沪過水の $KMnO_4$ 消費量は植物性プランクトンの減少に伴つて減少した。

10) 栄養塩類の NH_4–N, NO_2–N, NO_3–N, PO_4–P は輪虫の増殖期から，特にその最大個体数密度に達してからの斃死期に顕著に増加する。これは輪虫の斃死体から分解溶出するものと思われる。

11) 上述の *Br. plicatilis* の大増殖，植物性プランクトンの急激な減少，並にそれ等に伴う池水の水質の変化様式は，天然の養鰻池における輪虫類の異常増殖を伴つた水変りに見られる現象に全く一致する。

12) 従つて実際の養鰻池における水変り現象は輪虫類の異常増殖とその顕著な植物性プランクトンの捕食作用によつても充分説明出来る。即ち後者が養鰻池における水変りの有力な1因といえよう。

引　用　文　献

稲葉　峻 (1937). 養鰻池の水変りに関する予察的研究。魚介類斃死原因調査報告，第 II 報，静岡県水産試験場浜名湖分場，pp. 39.

稲葉　峻・山本精二 (1938). 養鰻池に於ける水変りの水質とプランクトンの研究。魚介類斃死原因調査報告，第 III 報，静岡県水産試験場月報，No. 46, p. 10〜23.

稲葉　峻・清石礼蔵 (1942). 鰻養殖に関する研究. 静岡県水産試験場浜名湖分場，pp. 30.

伊藤　隆 (1955 a). 三重県養鰻池における水質とプランクトンとの関係。鰻のシンポジウム，p. 19〜30. 日本水産学会中部支部。

——— (1955 b). 養鰻池の水変りに関する研究 I. Brachionus plicatilis (輪虫類) によるプランクトン植物の捕食作用 (水変りの1因として). Report of Faculty of Fisheries, Prefectural University of Mie, Vol. 2, No. 1, p. 162〜167.

——— (1955 c). 養鰻池の水変りに関する研究 II. Brachionus Plicatilis による水変りにおける $pH \cdot O_2$ の変化，Report of Faculty of Fisheries, Prefectural University of Mie, Vol. 2, No. 1, p. 168〜177.

伊藤隆・岩井寿夫. 養鰻池の水変りに関する研究. 津市江戸橋附近の6面の養鰻池における水変り. Report of Faculty of Fisheries, Prefectural University of Mie, (未発表).

松江吉行 (1954). 水中の炭酸と生物，第 27 回全国湖沼河川養殖研究会要録 (岡山)。p. 50〜63.

松江吉行・平野礼次郎 (1956). 水中の総炭酸量と植物プランクトン繁殖との関係について。陸水雑，Vol. 17, No. 4, p. 133〜140.

三宅泰雄・松居秀夫 (1943). 水の化学分析法，pp. 282, 東京.

菅原　健 (1942). 陸水化学，化学実験学，第 1 部，地球化学，p. 515〜594, 東京.

吉井義一・渡部哲光 (1956). 核分裂生成物のプランクトンによる除去，科学，Vol. 26, No. 27 p. 363〜364.

吉村信吉 (1939). 湖沼学，p. 41, 東京.

中村中六 (1949). 養魚池の水温に及ぼすアオコの影響，陸水雑，Vol. 14, p. 122〜126.